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ABSTRACT

This document is an instructional module package prepared in objective form for use by an instructor familiar with the basic concepts of biology related to water/wastewater technology. Included are objectives, instructor guides, student handouts, and transparency masters. The module considers organisms and their relationship, cell structures, classification of organisms, microbiological concerns in water supply systems and microbiological concerns in wastewater treatment. (Author/RH)

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BIOLOGY FOR OPERATORS

Training Module 1.311.2.77

Prepared for the

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by

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September, 1977

SE 004 000

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Module No:	Module Title: Biology for Operators
	Submodules
Approx. Time: 32 hours	1. Organisms & Their Relationships 2. Water Supply Concerns 3. Wastewater Stabilization

Overall Objectives:

Upon completion of this module, the participant should be able to describe classification and relations or organisms, identify water supply concerns with respect to biology, and describe the biological activity of the various phases of wastewater stabilization.

Instructional Aids:

Handouts A-1, A-2, A-3, A-4, B, and C

Instructional Approach:

Lecture
Discussion

References:

1. Weisz, Elements of Biology, McGraw Hill, New York 1969
2. Wetzel, Limnology, W. B. Saunders Co., Philadelphia, 1975
3. Pelczar & Reed, Microbiology, McGraw Hill, New York, 1958
4. McKinney, R., Microbiology for Sanitary Engineers, McGraw Hill, N. Y. 1962
5. MOP 11, Wastewater Pollution Control Federation, 1976
6. Campbell & Lehr, Water Well Technology, McGraw Hill, New York, 1973
7. Ford & Monroe, Living Systems, Canfield Press, San Francisco, 1977
8. Mitchell, Ralph, Introduction to Environmental Microbiology, Prentice Hall, Englewood Cliffs, N. J., 1974.

Class Assignments:

Module No:	Topic: SUMMARY

Instructor Notes:	Instructor Outline:
Handout A-1	1. Discuss basic cellular structure and function.
Handouts A-2 A-3 A-4	2. Describe the current classification system discussing each of the 4 kingdoms.
Handout B	1. Discuss the biological water supply concerns
Handout C	1. Discuss the biology of wastewater and wastewater stabilization with respect to process.
Note: Transparancies masters may be made from diagrams in the handouts as deemed necessary by the instructor.	

Module No:	Module Title: Biology for Operators
	Submodule Title: Organisms and Their Relationships
Approx. Time: 1 hour	Topic: Basic Cell Structure and Function

Objectives:

Upon completion of this module the participant should be able to identify characteristic cell structures and their respective functions.

Instructional Aids:

Handout A-1

Instructional Approach:

Lecture
Discussion

References:

1. Weisz, Elements of Biology, McGraw Hill, New York, 1969
2. Ford & Monroe, Living Systems, Canfield Press, San Francisco, 1977

Class Assignments:

Module No:	Topic: Basic Cell Structure and Function

Instructor Notes:	Instructor Outline:
Handout A-1	1. Discuss the basic cell structure relating structure to: a. Respiration b. Synthesis c. Genetic information storage
2. Include discussion of bianary fission and mitosis. a. Relate cell type to reproduction method b. Compare bianary fission and mitosis	2. Discuss cellular reproduction

Module No:	Module Title: Biology for Operators
	Submodule Title: Organisms and Their Relationships
Approx. Time: 1 hour	Topic: Classification of Organisms

Objectives:

Upon completion of this module, the participant should be able to:

1. Identify why viruses are considered "misfits" in most classification schemes.
2. Explain the rational behind the 3, 4, & 5 kingdom classification scheme.
3. Classify an organism as to kingdom using the 3 kingdom scheme.

Instructional Aids:

Handout A-1

Instructional Approach:

Lecture
Discussion

References:

1. Weisz, Elements of Biology, McGraw Hill, New York 1969
2. Ford & Monroe, Living Systems, Canfield Press, San Francisco, 1977

Class Assignments:

Read Handout #1

Module No:	Topic:
–	Classification of Organisms

Instructor Notes:	Instructor Outline:
Handout A-1	
1. Emphasize a. Divisions 1. Plant 2. Animal b. Problems encountered in classifying certain organisms	1. Describe the 2 kingdom system of classification
2. Emphasize a. Divisions 1. Plant 2. Animal 3. Protista 4. Monera b. How organism classified c. Emphasize relationship of cell structure and organism classification.	2. Describe the 4 kingdom system of classification
3. Emphasize the non-cellular structure of viruses	3. Discuss viruses and how they fit into the realm of organism classification
4. Emphasize rationale for divisions and sub-divisions a. Plant b. Animal c. Protists 1. Higher 2. Lower 3. Viruses	4. Discuss the 3 kingdom system of classification
5. Emphasize rationale for divisions a. Plant b. Animal c. Protista d. Monera e. Virus	5. Discuss the 5 kingdom system of classification

Module No:	Module Title: Biology for Operators
	Submodule Title: Organisms and Their Relationships
Approx. Time: 3 hours	Topic: Plant Kingdom

Objectives:

Upon completion of this module the participant should be able to:

1. List the general characteristics of the plant kingdom.
2. Organize the necessary processes for plant nutrition and synthesis.
3. Describe the structure and life cycle of bryophytes and tracheophytes.

Instructional Aids:

Handout A-2

Instructional Approach:

Lecture
Discussion

References:

1. Weisz, Elements of Biology, McGraw Hill, New York 1969
2. Ford & Monroe, Living Systems, Canfield Press, San Francisco, 1977

Class Assignments:

Read Handout #1

Module No:	Topic: Plant Kingdom

Instructor Notes:	Instructor Outline:
Handout A-2	1. Discuss general characteristice of the plant kingdom including: a. Structure b. Nutrition c. Respiration d. Synthesis e. Motility 2. Discuss the bryophytes including descriptions of a. Structures b. Reproduction 3. Discuss the tracheophytes including descriptions of a. Structures b. Reproduction c. Growth

Module No:	Module Title: Biology for Operators
	Submodule Title: Organisms and Their Relationship
Approx. Time: 3 hours	Topic: Animal Kingdom

Objectives:

Upon completion of this module, the participant should be able to describe the animal kingdom with respect to:

1. General animal characteristics
2. Divisions within the animal kingdom
3. Body structures represented
4. Basic nutrition, synthesis and respiration patterns
5. Representative life cycles and reproduction methods

Instructional Aids:

Handout A-3

Instructional Approach:

Lecture
Discussion

References:

1. Weisz, Elements of Biology, McGraw Hill, New York 1969
2. Ford & Monroe, Living Systems, Canfield Press, San Francisco, 1977

Class Assignments:

Read Handout #1

Module No:	Topic: Animal Kingdom

Instructor Notes:	Instructor Outline:
Handout A-3	1. Discuss general characteristics of the animal kingdom 2. List the phyla within the animal kingdom and relate the following: a. Structure b. Nutrition and synthesis c. Respiration d. Life cycles and reproduction methods

Module No:	Module Title: Biology for Operators
	Submodule Title: Organisms and Their Relationship
Approx. Time: 2 hours	Topic: Protista - Monera

Objectives:

Upon completion of this module, the participant should be able to:

1. List general characteristics of the protista and monera.
2. Show how the protista and monera differ from both plants and animals.
3. Identify why viruses are considered misfits in most classification schemes.

Instructional Aids:

Handout A-4

Instructional Approach:

Lecture
Discussion

References:

1. Weisz, Elements of Biology, McGraw Hill, New York 1969
2. Ford & Monroe, Living Systems, Canfield Press, San Francisco, 1977

Class Assignments:

Read Handout #1

Module No:	Topic: Protista - Monera

Instructor Notes:	Instructor Outline:
Handout A-4	1. Discuss the characteristics of the protista group and how these organisms differ from: a. Animals b. Plants 2. Discuss the characteristics of the monera group and how these organisms differ from: a. Animals b. Plants 3. Discuss the characteristics of viruses.

Module No:	Module Title: Biology for Operators
	Submodule Title: Organisms and Their Relationship
Approx. Time: 2 hours	Topic: Relationships

Objectives:

Upon completion of this module, the participant should be able to illustrate an inter-relationship between the growth cycles of monera, protista, plant and animal groups.

Instructional Aids:

None

Instructional Approach:

Lecture
Discussion

References:

1. Weisz, Elements of Biology, McGraw Hill, New York 1969
2. Pelczar & Reed, Microbiology, McGraw Hill, New York, 1958
3. Ford & Monroe, Living Systems, Canfield Press, San Francisco, 1977

Class Assignments:

Read Handout #1

Module No:	Topic: Relationships

Instructor Notes:	Instructor Outline:
1. Use terminology including: a. Sumbiosis b. Parasitic c. Energy flow d. Saprophytic e. Synergistic Note: Refer to Natural Systems Module for handout material.	1. Discuss and illustrate kingdom inter-relationships including: a. Plant - Animal 1. Respiration 2. Food chain b. Plant - Protista 1. Life cycles 2. Food chain c. Animal - Protista 1. Food chain 2. Life cycles d. Plant - Monera 1. Food chain 2. Life cycles e. Animal - Monera 1. Food chain 2. Life cycles

Module No:	Module Title: Biology for Operators
	Submodule Title: Water Supply Concerns
Approx. Time: 2 hours	Topic: Iron and Sulfate Reducing Bacteria

Objectives:

Upon completion of this module, the participant should be able to:

1. Identify the habitat and problems caused by iron bacteria, sulfate reducing bacteria, and slime formers in:
   a. Wells
   b. Pipes
   c. Surface water supply
2. Explain measures which can be taken to correct or improve a problem situation.

Instructional Aids:

Handout B

Instructional Approach:

Lecture
Discussion

References:

1. Wetzel, Limnology, W. B. Saunders Co., Philadelphia, 1975
2. Pelczar & Reed, Microbiology, McGraw Hill, New York, 1958
3. Campbell & Lehr, Water Well Technology, McGraw Hill, New York, 1973
4. Mitchell, Ralph, Introduction to Environmental Microbiology, Prentice Hall, Englewood Cliffs, N. J., 1974.

Class Assignments:

Read Handout #2

Module No:	Topic: Iron & Sulfate Reducing Organisms

Instructor Notes:	Instructor Outline:
Handout B 1. Identify & illustrate differences 2. Identify and illustrate differences	1. Discuss the growth cycle of iron bacteria: a. Sheathed b. Stalked 2. Discuss the growth cycle of sulfate reducing bacteria. 3. Discuss problems caused by iron bacteria, sulfate reducing bacteria and slime formers in: a. Wells b. Pipes c. Surface water 4. Discuss chlorine treatments used to improve or correct a problem situation.

Module No:	Module Title: Biology for Operators
	Submodule Title: Water Supply Concerns
Approx. Time: 2 hours	Topic: Algae & Nuisance Bacteria

Objectives:

Upon completion of this module the participant should be able to:

1. Describe the nuisance characteristics of algae and bacteria growth including production of:
   a. Turbidity
   b. Discoloration
   c. Odor
   d. Taste

2. List the various methods of algae and nuisance bacteria control.

Instructional Aids:

Handout B

Instructional Approach:

Lecture
Discussion

References:

1. Wetzel, Limnology, W. B. Saunders Co., Philadelphia, 1975
2. Pelczar & Reed, Microbiology, McGraw Hill, New York, 1958
3. Campbell & Lehr, Water Well Technology, McGraw Hill, New York, 1973

Class Assignments:

Read Handout #2

Module No:	Topic: Algae

Instructor Notes:	Instructor Outline:
Handout B 1. Include examples of: a. Turbidity b. Discoloration c. Odor d. Taste	1. Discuss the nuisance characteristics of algae growth including a description of the different algae types and which characteristics are associated with each. 2. Discuss the nuisance characteristics of bacteria growth including a description of the different bacteria types and which characteristics are associated with each.

Module No:	Module Title: Biology for Operators
	Submodule Title: Water Supply Concerns
Approx. Time: 1 hour	Topic: Pathogens

Objectives:

Upon completion of this module, the participant should be able to:

1. Identify sources and effects of pathogens
2. Specify limitations and assumptions in method of:

    a. Detection
    b. Removal or destruction

Instructional Aids:

Handout B

Instructional Approach:

Lecture
Discussion

References:

1. Wetzel, Limnology, W. B. Saunders Co., Philadelphia, 1975
2. Pelczar & Reed, Microbiology, McGraw Hill, New York, 1958
3. Campbell & Lehr, Water Well Technology, McGraw Hill, New York, 1973
4. Mitchell, Ralph, Introduction to Environmental Microbiology, Prentice Hall, Englewood Cliffs, N. J., 1974.

Class Assignments:

Read Handout

Module No:	Topic: Pathogens

Instructor Notes:	Instructor Outline:
Handout B 1. Emphasize a. Source b. Effect 2. Emphasize a. Limitations b. Assumptions	1. Discuss water borne pathogens 2. Discuss detection, removal and destruction of pathogens in a drinking water supply.

Module No:	Module Title: Biology for Operators
	Submodule Title: Water Supply Concerns
Approx. Time: 1 hour	Topic: Higher Plant and Animals

Objectives:

Upon completion of this module the participant should be able to identify biological problems where sources are higher plants and animals.

Instructional Aids:

Handout B

Instructional Approach:

Lecture
Discussion

References:

1. Wetzel, Limnology, W. B. Saunders Co., Philadelphia, 1975
2. Pelczar & Reed, Microbiology, McGraw Hill, New York, 1958
3. Campbell & Lehr, Water Well Technology, McGraw Hill, New York, 1973
4. Mitchell, Ralph, Introduction to Environmental Microbiology, Prentice Hall, Englewood Cliffs, N. J., 1974.

Class Assignments:

Read Handout #2

Module No:	Topic: Higher Plant and Animals

Instructor Notes:	Instructor Outline:
Handout B 1. Indicate: a. Wastes b. Decay c. Over-growth	1. Discuss biological problems whose sources are higher plants and animals. a. In surface water b. In wells

Module No:	Module Title: Biology for Operators
	Submodule Title: Wastewater Stabilization
Approx. Time: 2 hours	Topic: Domestic Wastewater

Objectives:

Upon completion of this module, the participant should be able to:

1. Illustrate how disease is transmitted through fecal matter.
2. Describe the biological activity of untreated sewage.

Instructional Aids:

Handout C

Instructional Approach:

Lecture
Discussion

References:

1. Pelczar & Reed, Microbiology, McGraw Hill, New York, 1958
2. McKinney, R., Microbiology for Sanitary Engineers, McGraw Hill, New York, 1962
3. MOP 11, Wastewater Pollution Control Federation, 1976

Class Assignments:

Read handout #3

Module No:	Topic: Domestic Wastewater

Instructor Notes:	Instructor Outline:
Handout C 1. List diseases and illustrate pathways 2. Emphasize: a. Disease transmission b. Odor c. Step-by-step process	1. Discuss disease transmission through fecal matter a. Cross connections b. Insufficient treatment 2. Discuss the natural process of decomposition of domestic wastes.

Module No:	Module Title: Biology for Operators
	Submodule Title: Wastewater Stabilization
Approx. Time: 1 hour	Topic: Primary Treatment

Objectives:

Upon completion of this module, the participant should be able to differentiate between the biological activity of the raw wastewater, primary effluent, and settled matter.

Instructional Aids:

Handout C

Instructional Approach:

Lecture
Discussion

References:

1. Pelczar & Reed, Microbiology, McGraw Hill, New York, 1958
2. McKinney, R., Microbiology for Sanitary Engineers, McGraw Hill, New York, 1962
3. MOP 11, Wastewater Pollution Control Federation, 1976

Class Assignments:

Read Handout #3

Module No:	Topic: Primary Treatment

Instructor Notes:	Instructor Outline:
Handout C	1. Discuss the biological activity of: a. Raw wastewater b. Primary effluent c. Settled matter
2. Use a chart	2. Illustrate the differences

Module No:	Module Title: Biology for Operators
	Submodule Title: Wastewater Stabilization
Approx. Time: 1 hour	Topic: Trickling Filters

Objectives:

Upon completion of this module, the participant should be able to describe the biological activity of a trickling filter.

Instructional Aids:

Handout C

Instructional Approach:

Lecture
Discussion

References:

1. Pelczar & Reed, Microbiology, McGraw Hill, New York, 1958
2. McKinney, R., Microbiology for Sanitary Engineers, McGraw Hill, New York, 1962
3. MOP 11, Wastewater Pollution Control Federation, 1976

Class Assignments:

Read Handout

Module No:	Topic: Trickling Filter
Instructor Notes:	Instructor Outline:
Handout C	1. Discuss the biological activity on a trickling filter including: a. Micro-layers and populations of each b. Limiting factors c. Competition d. Nutritional requirements

Module No:	Module Title: Biology for Operators
	Submodule Title: Wastewater Stabilization
Approx. Time: 1 hour	Topic: Rotating Biological Discs

Objectives:

Upon completion of this module, the participant should be able to describe the biological activity on rotating biological discs.

Instructional Aids:

Handout C

Instructional Approach:

Lecture
Discussion

References:

1. Pelczar & Reed, Microbiology, McGraw Hill, New York, 1958
2. McKinney, R., Microbiology for Sanitary Engineers, McGraw Hill, New York, 1962
3. MOP 11, Wastewater Pollution Control Federation, 1976

Class Assignments:

Read Handout #3

Module No:	Topic: Rotating Biological Discs

Instructor Notes:	Instructor Outline:
Handout C	1. Discuss the biological activity on a rotating biological disc including: a. Micro-layers and populations of each b. Limiting factors c. Competition d. Nutritional requirements

Module No:	Module Title: Biology for Operators
	Submodule Title: Wastewater Stabilization
Approx. Time: 1 hour	Topic: Activated Sludge

Objectives:

Upon completion of this module, the participant should be able to describe the biological activity in activated sludge.

Instructional Aids:

Handout C

Instructional Approach:

Lecture
Discussion

References:

1. Pelczar & Reed, Microbiology, McGraw Hill, New York, 1958
2. McKinney, R., Microbiology for Sanitary Engineers, McGraw Hill, New York, 1962
3. MOP 11, Wastewater Pollution Control Federation, 1976

Class Assignments:

Read Handout #3

Module No:	Topic: Activated Sludge

Instructor Notes:	Instructor Outline:
Handout C	1. Discuss the biological activity in activated sludge including: a. Population b. Limiting factors c. Competition d. Nutritional requirements

Module No:	Module Title: Biology for Operators
	Submodule Title: Wastewater Stabilization
Approx. Time: 1 hour	Topic: Lagoons

Objectives:

Upon completion of this module, the participant should be able to describe the biological activity in a lagoon.

Instructional Aids:

Handout C

Instructional Approach:

Lecture
Discussion

References:

1. Pelczar & Reed, Microbiology, McGraw Hill, New York, 1958
2. McKinney, R., Microbiology for Sanitary Engineers, McGraw Hill, New York, 1962
3. MOP 11, Wastewater Pollution Control Federation, 1976

Class Assignments:

Read Handout #3

Module No:	Topic: Lagoons

Instructor Notes:	Instructor Outline:
Handout C	1. Discuss the biological activity in a lagoon including: a. Populations b. Limiting factors c. Competition d. Nutritional requirements

Module No:	Module Title: Biology for Operators
	Submodule Title: Wastewater Stabilization
Approx. Time: 1 hour	Topic: Sludge Digestion

Objectives:

Upon completion of this module, the participant should be able to describe the biological activity necessary for:

1. Aerobic sludge digestion
2. Anaerobic sludge digestion

Instructional Aids:

Handout C

Instructional Approach:

Lecture
Discussion

References:

1. Pelczar & Reed, Microbiology, McGraw Hill, New York, 1958
2. McKinney, R., Microbiology for Sanitary Engineers, McGraw Hill, New York, 1962
3. MOP 11, Wastewater Pollution Control Federation, 1976

Class Assignments:

Read Handout #3

Module No:_	Topic: Sludge Digestion

Instructor Notes:	Instructor Outline:
Handout C	1. Discuss aerobic sludge digestion with respect to what biological activity is necessary including: a. Populations b. Limiting factors c. Competition d. Nutritional requirements 2. Discuss anaerobic sludge digestion with respect to what biological activity is necessary including: a. Populations b. Limiting factors c. Competition d. Nutritional requirements

Module No:	Module Title: Biology for Operators
	Submodule Title: Wastewater Stabilization
Approx. Time: 1 hour	Topic: Disinfection

Objectives:

Upon completion of this module, the participant should be able to identify the action of a disinfectant on the microbiological community.

Instructional Aids:

Handout C

Instructional Approach:

Lecture
Discussion

References:

1. Pelczar & Reed, Microbiology, McGraw Hill, New York, 1958
2. McKinney, R., Microbiology for Sanitary Engineers, McGraw Hill, New York, 196
3. MOP 11, Wastewater Pollution Control Federation, 1976

Class Assignments:

Read Handout #3

Module No:	Topic: Disinfection

Instructor Notes:	Instructor Outline:
Handout C Emphasize 1. Chlorine 2. Ozone	1. Discuss the action of disinfectants on the microbial population within the water

Module No:	Module Title: Biology for Operators
	Submodule Title: Wastewater Stabilization
Approx. Time: 1 hour	Topic: Effluent and Receiving Stream

Objectives:

Upon completion of this module the participant should be able to identify the effect of an effluent on a receiving stream.

Instructional Aids:

Handout C

Instructional Approach:

Lecture
Discussion

References:

1. Pelczar & Reed, Microbiology, McGraw Hill, New York, 1958
2. McKinney, R., Microbiology for Sanitary Engineers, McGraw Hill, New York, 19
3. MOP 11, Wastewater Pollution Control Federation, 1976

Class Assignments:

Read Handout #3

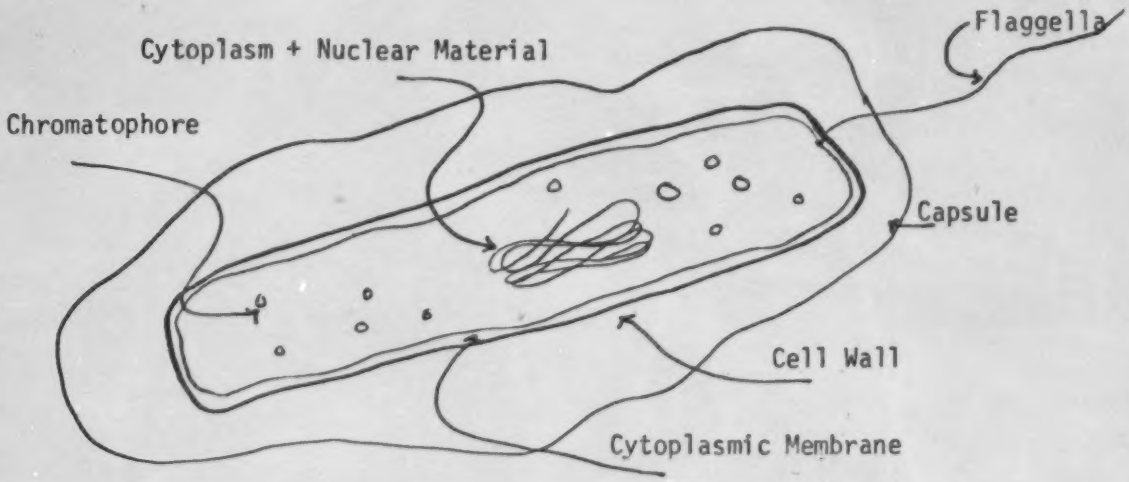
Module No:	Topic: Effluent and Receiving Stream

Instructor Notes:	Instructor Outline:
Handout C 1. Differentiate the effects of a good quality effluent and a poor quality effluent with examples.	1. Discuss the effect of the effluent on the receiving stream with respect to: a. Effluent quality b. Flow rate of stream

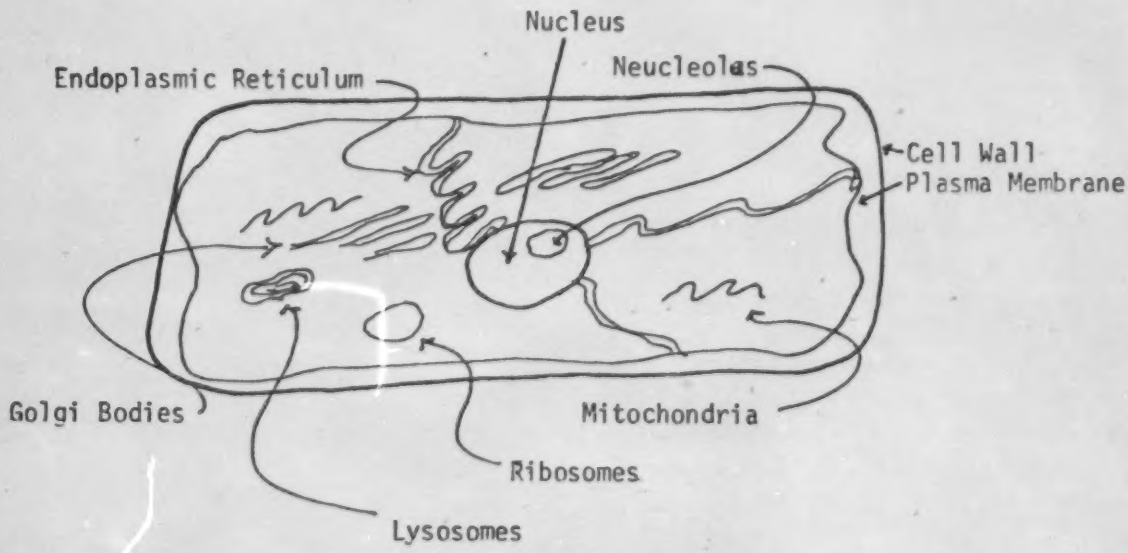
THE CELL

Cell Structure

There are two fundamental cell types. These two, the procaryotic cell and the eucaryotic cell, are diagrammed below.



Procaryotic Cell



Eucaryotic Cell

Cell Functions

The procaryotic cell is a more primitive cell than the aucaryotic cell. This can be seen from comparing the two diagrams. In the procaryotic cell the function of each of the structures as shown in the following table.

Structure	Function
Cell Wall	Gives shape, support and protection to the cell
Plasma Membrane	Semi-permeable membrane which controls the movement of nutrients and other materials into and out of the cell.
Cytoplasm	The non-membrane material within the plasma membrane which contains the dissolved nutrients and other substances necessary for the life functions carried on by the cell.
Chromatophore	Granuoles in the photosynthetic eucaryotic cells containing the photosynthetic pigments.

The eucaryotic cell shown is a composit drawing. No one cell contains all the structures shown. The function of each of the structures shown in the composit eucaryotic cell diagrammed is given in the following table. The structures are grouped as to location within the cell to aid in relating functions.

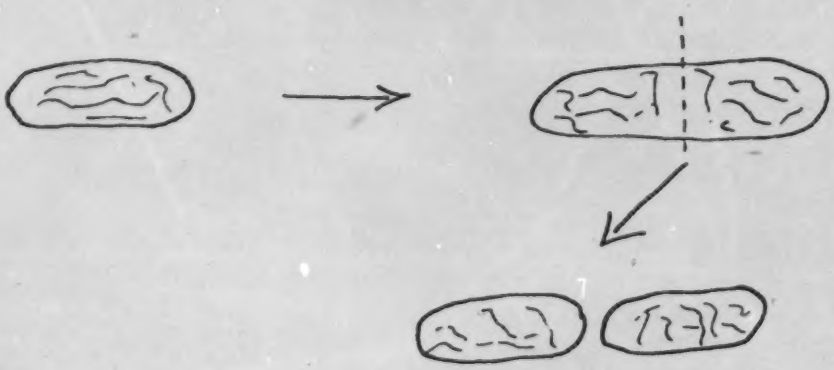
Location	Structure	Function
Outer Structures	Cuticles, Pellicies	Gives support and protection to cell, and provides type of waterproofing.
	Cilia, Flagella	Provides a method for creating a current for movement and food retrieval.
	Pseudopodia	Provides a method for locomotion and engulfing food for phagosytosis by arm like extensions.
	Cell Wall	Gives shape, support and protection to cell.
	Plasma Membrane	Semi-permeable membrane which controls the movement of nutrients and other materials into and out of the cell.
Cytoplasm of Cell	Centrioles	Points to which materials move during cell division.
	Chloroplasts	Site of photosynthesis
	Endoplasmic Reticulum	Continuous double membranes which connect the plasma and nuclear membranes and function as conducting channels and as intercellular framework.
	Golgé bodies	Manufacturing site of cellular secretion products.
	Granules & Vacuoles	Bodies which transport or store nutrients, secretion products or wastes.
	Kinetosomes	Structure on cell wall which attaches flagella & cillia to all and controls their movement.
	Mitochondria	Site of respiration

Location	Structure	Function
Cytoplasm of Cell	Lysosomes	Stores digestive enzymes which are released upon death of cell.
	Ribosomes	Site of protein synthesis
Nucleus	Nuclear Membrane	Membrane which bounds nucleus and controls flow between nucleus and cytoplasm.
	Nucleolus	Controls protein synthesis
	Chromosomes	Gene structure which controls all cellular activities.

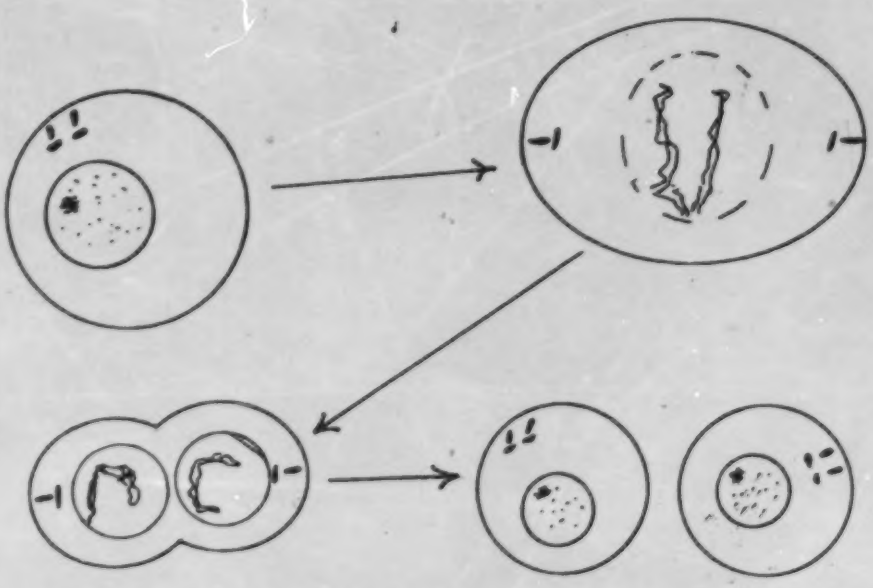
Cellular Reproduction

Though organismic reproduction can occur in a variety of ways, there are only two basic methods for cellular division. These two processes are bianary fission and budding.

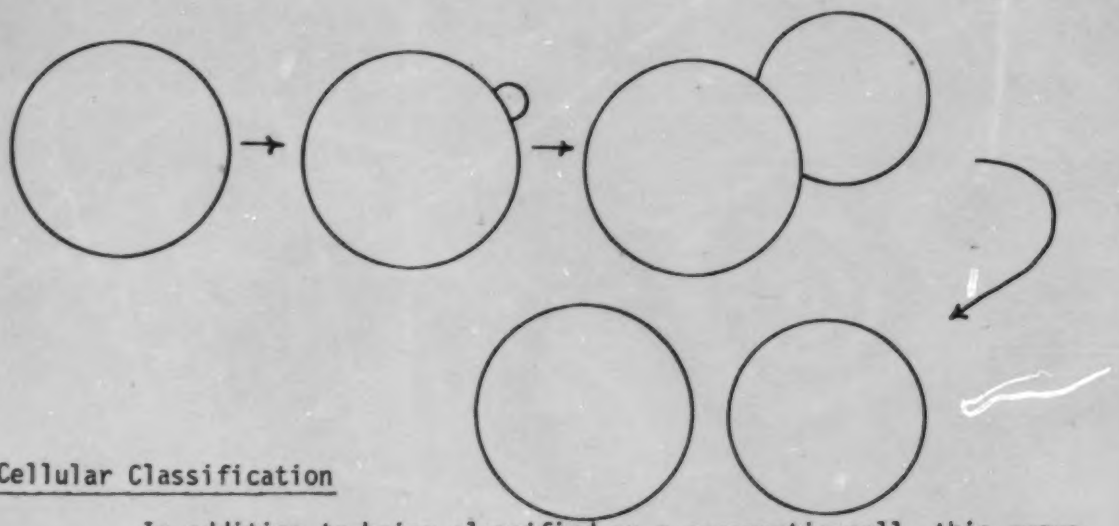
The procaryotic cell normally divides by simple binary fission. Since there is no nucleus the dispersed genetic material duplicates and arranges half on each side of the line of cleavage. The enlarged mother cell then divides into two equal daughter cells. This is diagrammed below.



The eucaryotic cell may divide by bianary fission process similar to that one described above. However, the eucaryotic cell has a distinct nucleus which goes through a definite reproductive pattern followed by the cytoplasmic cleavage. This process is termed mitosis and is diagrammed below.



The other method by which a few eucaryotic cells can divide is by budding. In this process, the mother cell sends out a tube from the nucleus into a small protruberance on the outer surface of the cell. This then fills with nuclear and cytoplasmic material as the bud enlarges. When the bud is nearly as large as the mother cell it detaches and the process begins again. This procedure can be shown diagramatically as follows:



Cellular Classification

In addition to being classified as a eucaryotic cell, this group can be further identified with respect to cell components into three cell classes. The characteristics of the three eucaryotic cell classes and the procaryotic cells can be summarized as follows.

Cell Type	Cell Group	Characteristics
Eucaryotic Cell	Plant Cell (plants)	Large central vacuole Chloroplasts Cell walls
	Animal Cells (animals)	Small scattered vacuoles Locomotion in most No chloroplasts Centrioles No cell walls
	Protistan Cells (algae, fungi protozoa and slime mold)	Some have locomotion and chlorophyll Some have locomotion and no chlorophyll Some have no locomotion nor chlorophyll Centrioles Cell walls containing cellulose

Cell Type	Cell Group	Characteristics
Procaryotic Cells	Moneran Cells or lower protistan cells (bacteria and blue-green algae)	No cellulose in cell walls No mitochondria No golgi apparatus No centrioles No lysosomes No nuclear membranes Chromatophores instead of chloroplasts DNA not organized into chromosomes

Organism Classification

In reviewing the cellular classification chart it is obvious that the system of classification with respect to taxonomy developed by the 18th century Swedish naturalist Carlous Linnaese developed problems. He classified organisms using body structure and evolutionary history into two kingdoms - plant and animal. With this system, algae and bacteria could not be classified since many exhibit both plant and animal characteristics and others exhibit neither.

The cellular structure proved a much more useable method of organism classification. By this method all cellular organisms are classifiable into one of the four kingdoms derived from cell structure types.

The four kingdoms are as follows:

Plant Kingdom (Metaphyta)

Animal Kingdom (Metazoa)

Protista

Monera

In order to further classify any organism, each kingdom is arranged into the following classification hierarchy:

Kingdom

Phylum

Class

Order

Family

Genus

Species

However, there is one group of organisms which still must be considered. These organisms the viruses. Since they are non-cellular they do not fit into the 4 kingdom classification scheme. Therefore many prefer one of the following schemes:

1. The 3 kingdom scheme with the protistan kingdom subdivided into subkingdoms as follows:

   Plant kingdom

   Animal kingdom

   Protistan kingdom

   Subkingdoms: Higher protists

   Lower protists

   Viruses

2. The 5 kingdom scheme of:

   Plant kingdom

   Animal kingdom

   Protistan kingdom (higher protists)

   Moneran kingdom (lower protists)

   Virus kingdom

THE PLANT KINGDOM

The plant kingdom is divided into two Phyla, the bryophytes and the tacheophytes.

Phylum Bryophyta

Mosses

Liverworts

Horn worts

Phylum Tracheophyta

Psilopsids

Club mosses

Horsetails

Ferns

Cone-bearing seed plants

Flowering seed plants

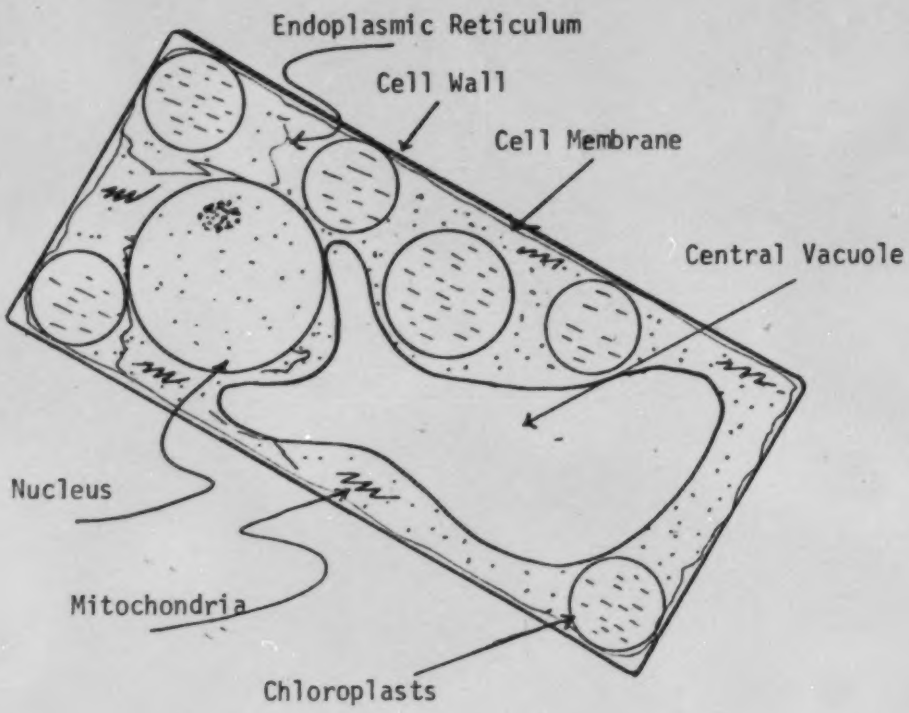
In looking at the plant kingdom several characteristics are basic to all the members. Included in these characteristics are:

1. Plants are composed of organ or organ-like structures which mismeratic tissue at tips of stems and roots.
2. Plants are non-mobile and respiration occurs without specialized breathing apparatus.
3. Plants synthesize nutritional requirements other than those absorbed by photosynthesis using chlorophyll a and b.

4. Plant life cycles alternate between saprophyte and gametophyte generations.
5. Plants contain multicelled reproductive organs which produce multicelled embryos.

These 5 characteristics are discussed in the following pages.

Basic Cellular Structures



Motility

As can be noted from the above diagram plants have no specialized structure for locomotion and therefore are considered non-motile organisms.

Nutrition

Nutrition can be defined as the intake and distribution of raw materials to all cells within an organism. Nutritionally plants are classified as autophic organisms since they manufacture all necessary food from inorganic nutrients. In a plant the leaves and green stems are responsible for collecting aerial gases and manufacturing foods. The roots provide the structure for absorbtion of water and dissolved minerals and gases while the stems act as conduits transporting the materials between the roots and leaves.

These processes can easily be shown by the following diagrams. Note the specific structures within the leaves, stems and roots which are actively involved in collection, manufacture and transport of nutrients.

Respiration

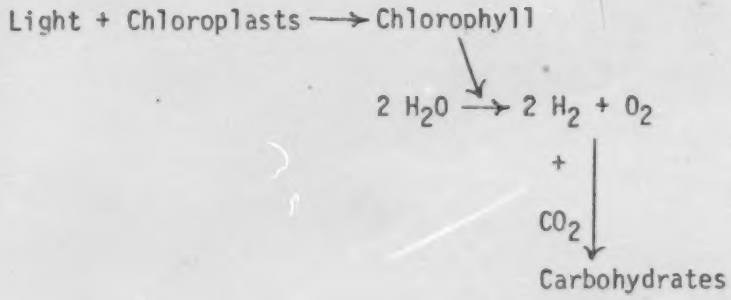
Respiration is a function performed by every cell within an organism. Therefore it is termed a cellular process. This process is responsible for the breaking down of the chemical bonds in the nutrient molecules yielding the energy necessary for metabolism (life sustaining processes). Since plant cells are in direct or near direct contact with atmospheric gases, no specialized breathing apparatus is necessary. Respiration can be broken down into three distinct processes. First organic compounds are broken down into energy, carbon dioxide, and free hydrogen, then the hydrogen combines with oxygen to form water and the energy is transferred into usable cellular energy.

Synthesis

Photosynthesis is the process by which plants produce basic foods and energy required for the cells to synthesize the more complex foods necessary for life processes. In photosynthesis, the plant absorbs carbon dioxide from the atmosphere and combines it with water to form carbohydrates. This chemical reaction can be written:

$$6\ CO_2 + 6\ H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_2 + 6\ O_2$$

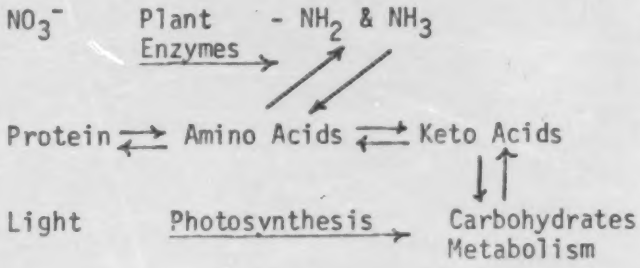
Note that this is a reaction which requires light and chlorophyll. The simple combination of water and carbon dioxide yields carbonated water. However, in this reaction, the green pigment (chlorophyll) decomposes water to hydrogen and oxygen before exposing the carbon dioxide to the free hydrogen. The decomposition process is termed photolysis as light is required. The next step where the carbon dioxide is combined with the hydrogen does not require light so it will occur in the dark. This chemical reaction can be written.



Both of these reactions occur in the chloroplasts of the green cell with the prime end product being PGAL (food). PGAL can be used directly as a nutrient for respiration or transformed into more stable products, i.e. sugars for transport to non-green tissues or starches and fats for storage in roots or stems. These stored carbohydrates (sugars, starches, and fats) are then used as needed by the plant cells as starting points for manufacture of more sophisticated building materials.

In the plant, amino acid synthesis takes place in the cell. Plants absorb mineral nitrate (NO_3^-) found in the soil and convert it to amino group ($-NH_2$) which is used to build amino acids. This absorbtion and conversion process is regulated by the cell so amino acid synthesis occurs only as required by the cell. Amino acids provide building blocks for a variety of manufacturing process, but, most importantly, amino acids are the beginnings for protein and nucleic acid synthesis.

We can combine amino acid synthesis activities with carbohydrate synthesis to form the following flow chart for plants.

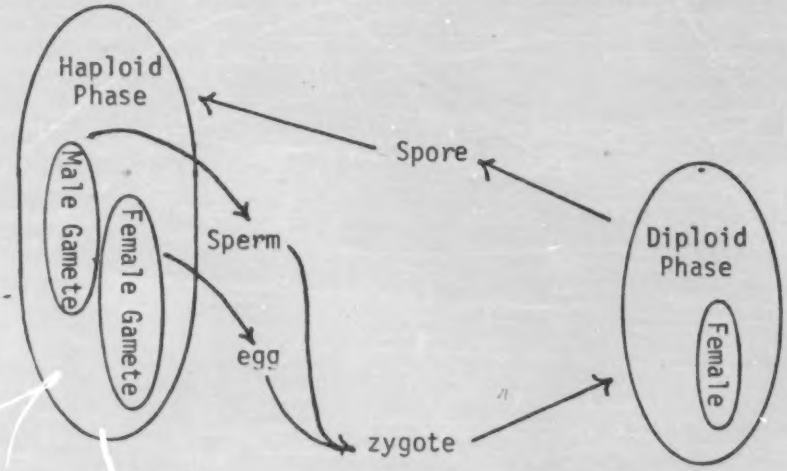


Life Cycles and Reproductive Patterns

Phylum Bryophyta

Bryophytes are important soil formers as they take over where lichens stop in the transformation of rock to soil. Also they act as soil protectors in the shady perpetually moist areas since they form dense soil covering carpets. This acts as an inhibitor to soil erosion and a retainer of water for plant use.

The life cycle and reproductive patterns of bryophytes can most easily be described by the following diagram. This is, specifically, the life cycle and reproductive pattern of a typical moss. However, it can be applied to most bryophytes.



Bryophytes may also reproduce with asexual buds or remain as continuous growth. However, regardless of the bryophyte, the gametophyte generation is dominant and they lack true roots, stems, and leaves.

Phylum Tracheophyta

The phylum tracheophyta comprises a much larger group of plants than does the phylum bryophyta. Therefore, the phylum is broken down into five sub-phylum.

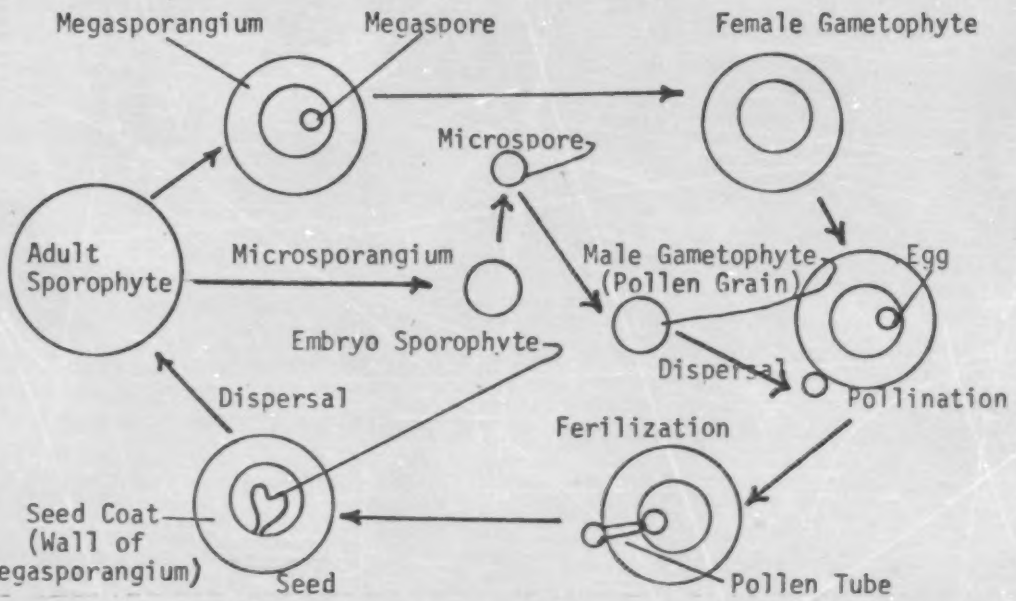
1. Psilopsida - primative vascular plants
2. Lycopsidea - club mosses
3. Sphenopsida - horsetails
4. Pteropsida - ferms
5. Spermopsida - seed plants

In looking at each of the five sub-phyla with respect to importance in today's ecology, life cycles and reproduction, the psilopsida, lycopsida, and sphenopsida play a very small part. They were important in past centuries but have been replaced by seed bearing plants. They appear to be the starting materials for todays coal reserves.

The pteropsida - ferns - are another primitive plant. A few species have survived the centuries and still fluorish today in the temperate zones. The life and reproductive cycles of the fern is very similar to that of the bryophyte.

The spermopsida are the dominant plant types today. They have evolved due to the production of seeds which contain an embryo with a food supply surrounded by a protective coat.

There are two major classes of spermapsida, the gymnosperm (cone bearing) and the angiosperm (flower or fruit producers. The gymnospherm are a major source of timber as they include firs, pines, hemlock and cedar. The life and reproductive cycles of the gymnosperms can be illustrated by the following diagram.



The angiosperm class represents the most complex of the plant kingdom. Their chief importance in today's environment is as a food source. This group includes the dicots which are our chief producers of fruits and vegetables and the monocots which supply our grain. The reproductive and life cycles are very similar to that of the gymnosperm which is diagrammed above.

Summary

From this it should be evident that plants have similar basic cellular structures, methods of obtaining nutrients, respiration, and synthesis. What differentiates one phylum from another is microscopic structures and reproductive cycles.

THE ANIMAL KINGDOM

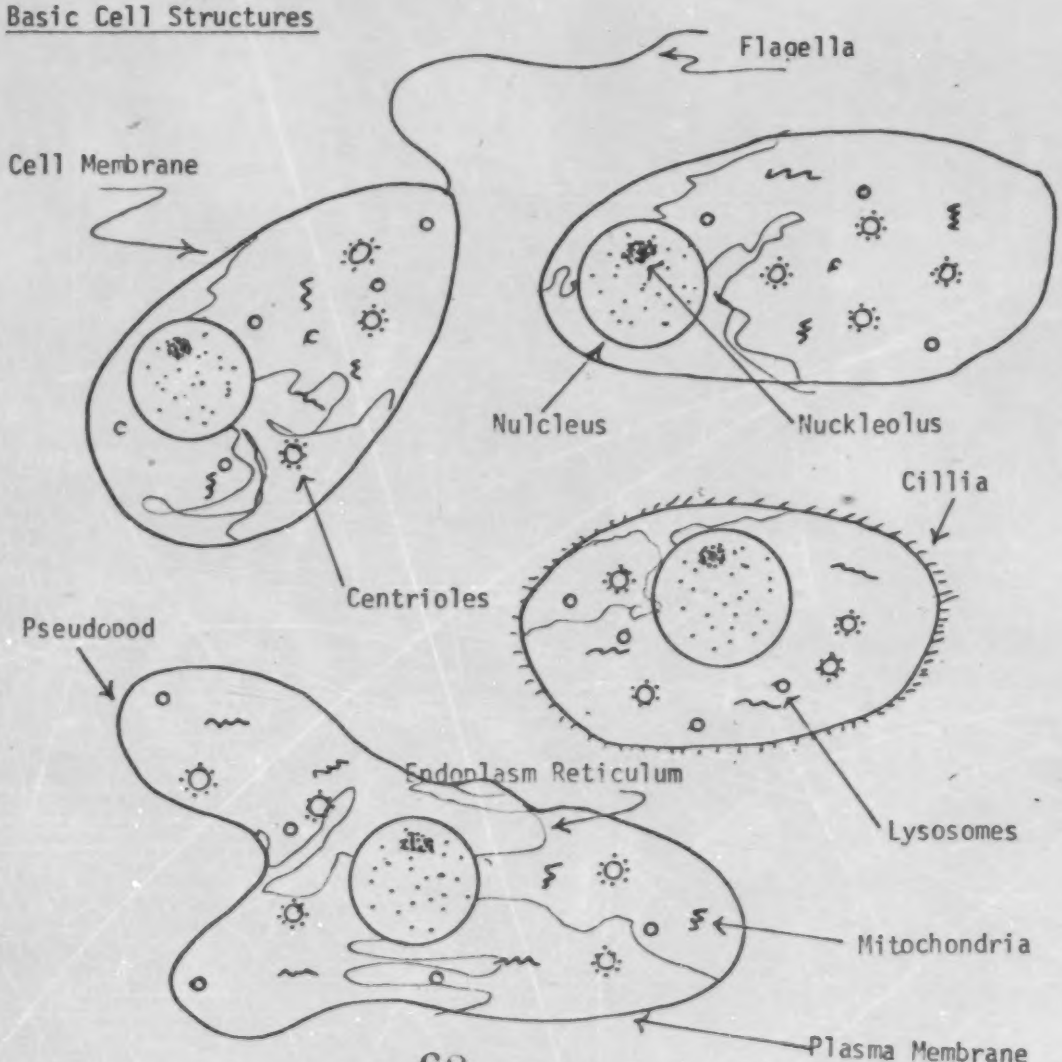
The animal kingdom is quite diversified. This can be seen by the following list of phyla.

1. Phylum Porifera - sponges
2. Phylum Cnidaria - jelly fish, coral
3. Phylum Ctenophora - comb jellies
4. Phylum Platyhelinthes - flat worms
5. Phylum Nemertina - proboscis and ribbon worms
6. Phylum Aschelminthes - sac worms, rotifers, nemitodes
7. Phylum Acanthocephala - spiney headed worms
8. Phylum Entoprocta - entoprocts
9. Phylum Phoronida - worm-like tube dwellers
10. Phylum Ectoprocta - moss animals
11. Phylum Brachiopoda - lamp shells
12. Phylum Mollusca - mollusks
13. Phylum Sipunculida - peanut worms
14. Phylum Annelida - segmented worms
15. Phylum Echuioroida - spoon worms
16. Phylum Oncopoda - segmented claw-bearing animals
17. Phylum Arthropoda - joint-legged animals
18. Phylum Chaetognatha - arrow worms
19. Phylum Hemichordata - corn worms
20. Phylum Pogonophora - beard worms
21. Phylum Echinoderma - spiney-skinned animals
22. Phylum Chordata - tunicates and sea squirts, amphiorus, vertabrates

Even with the diverse group, there are some characteristics common to all animals. These characteristics include:

1. Animals are not able to manufacture their own food (no chloroplasts).
2. Animals are not capable of infinite growth.
3. Animal cells have centrioles.
4. Animal cells combine to form tissues including muscle and nervous tissue.
5. Animal tissues form organs which combine functions into systems.

Basic Cell Structures



Basic Body Structures and Motility

In the animal kingdom there are three basic body structures, acoelomata, pseudocoelomata, and eucoelomata. The acollomates possess no body cavity. Examples of this class are sponges, jelly fish, and flatworms (Phylums #1 - 5 on page #1) and the pseudocoelomata possess an incomplete eta boned body cavity. These are worm-like structures (Phylum #5 - 8 on page #1).

The eucoelomata, on the other hand, are animals which possess a body cavity. This group is by far the largest of the three and includes the remaining phyla listed.

Since animals possess muscle tissue and nerve tissue, they are capable of much greater movement than plants and are considered motile. Many, however, require an aquatic environment in which to move. The greater locomotion allows animals a greater area in which to locate food as they cannot manufacture their own. Animals can either move to the food or cause the food to move toward itself by creating currents. (An example of this is in the sponge.)

Of those which move to their food, certain structures become necessary. First a head where sense organs can locate to identify the environment, also the mouth for intake of food. Elimination located at the opposite end so as not to impede forward motion.

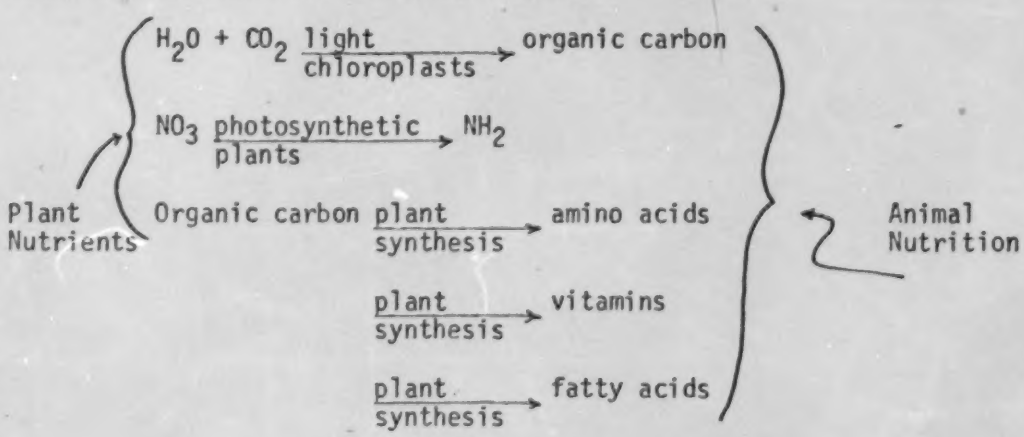
Since these animals are in motion, the body structure needs to be more compact than their non-motile plant counterpart. With this compact structure and no cell walls some form of support had to develop. Skeletal structures combined with the muscle tissue gives shape to the otherwise shapeless mass of cells.

With this more compact form, cells must be indirectly linked to the environment for their oxygen supply and waste removal. Circulatory systems developed to meet this requirement. Also breathing, excretory and reproductive systems have developed to meet the needs of these more complex organisms. These will be discussed in the following sections.

Nutrition

In most animals specialized structures are necessary for the intake and ease of nutrients. Nutrients are taken in through the mouth, digested in a stomach structure, wastes eliminated, and nutrients circulated.

Unlike a plant, animals cannot derive the necessary nutrients from only water, minerals, and organic carbon. Animals require complex organic carbon, amino acids, fatty acids, vitamins, and minerals. These additional materials are derived from plant matter.


$H_2O + CO_2$ light / chloroplasts → organic carbon
NO_3 photosynthetic plants → NH_2
Plant Nutrients
Organic carbon plant synthesis → amino acids
plant synthesis → vitamins
plant synthesis → fatty acids
Animal Nutrition

From this it is obvious that plant life is necessary for sustained animal life.

Once the essential nutrients are ingested digestion takes place. Digestion is a combination of mechanical and enzymatic processes which break

down the complex foods. These food components are then absorbed and recombined to form the needed complete nutrients. These absorbed nutrients are then either used for energy necessary to perform immediate body functions or stored for later use. The conversion of the absorbed nutrients into energy for metabolic use is done by a controlled combustion process - respiration.

Respiration

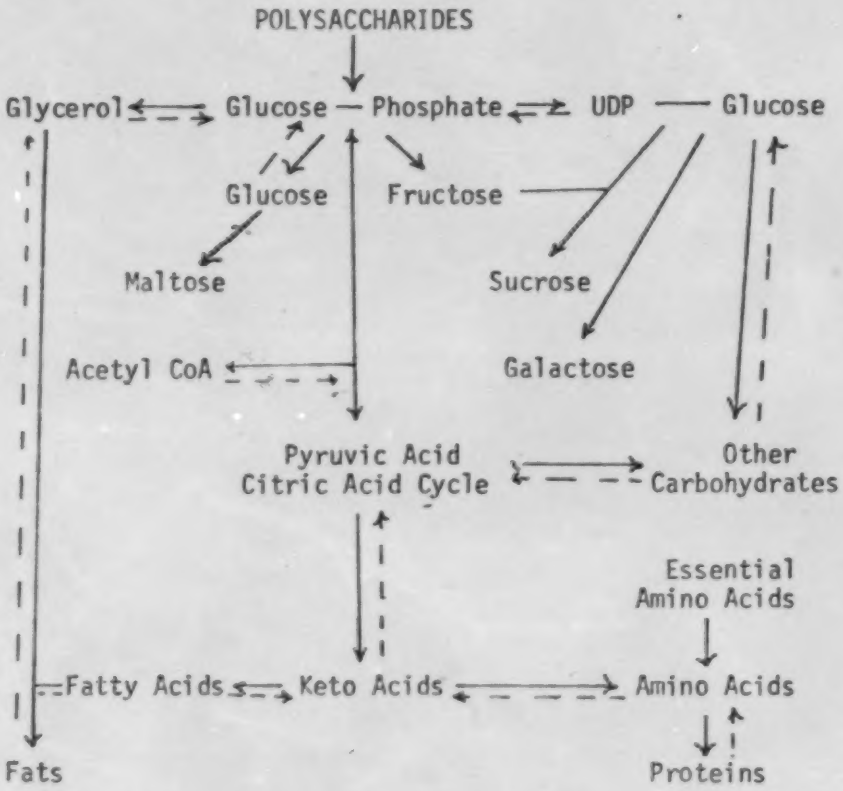
As in plants, animal respiration is also a cellular process and responsible for the breaking down of the chemical bonds in the nutrient molecules yielding the energy necessary for metabolism. Since the body structure of animals is bulky most of the cells are not in direct contact with atmospheric gases. Therefore, specialized breathing apparatus and systems through which atmospheric gases (primarily oxygen, O_2) may be distributed to the various cells.

Respiration must be looked at as controlled combustion leading to release of energy--not simply the breathing function. As with plants, animal respiration encompasses three distinct processes. First organic compounds are broken down into energy, carbon dioxide, and free hydrogen, then the hydrogen combines with oxygen to form water and the energy is transformed into usable cellular energy.

In animals, respiration of carbohydrates, lipids, and amino acids follow different pathways. The resultant energy release however is common to all.

Synthesis

Nutrition and respiration have made AtP and nutrients available for synthesis. (Animals cannot fix CO_2 to form the basic organic compounds). Animal cells now can add CO_2 to existing organic chains to create the larger essential compounds. These metabolic synthesis pathways can best be illustrated by the following flow diagram.



Many of the above reactions are reversible (shown by dotted lines) and diagram the respiration degredation processes. Respiration, therefore, can be viewed as a simple reversal of synthesis.

Life Cycles and Reproductive Patterns

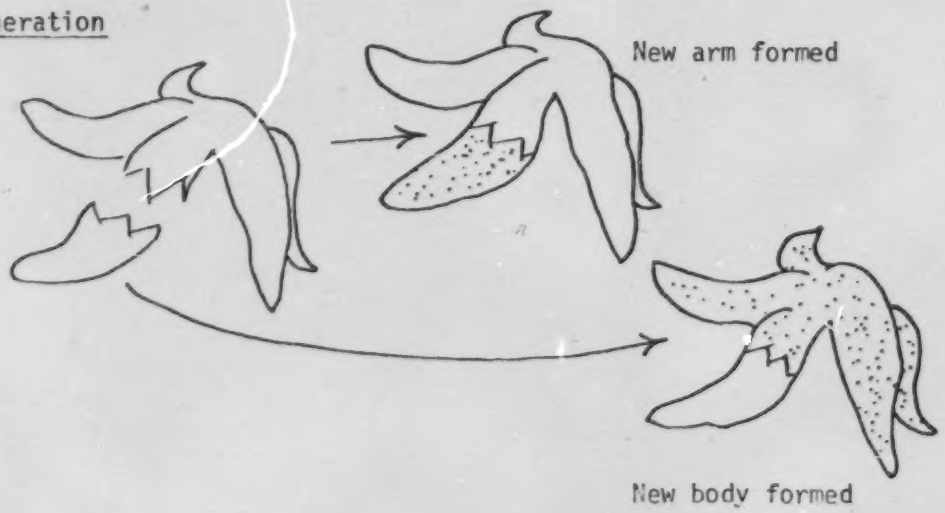
Unlike plants, animals of the same phyla do not necessarily reproduce following the same pattern. Nor are their life cycles necessarily similar.

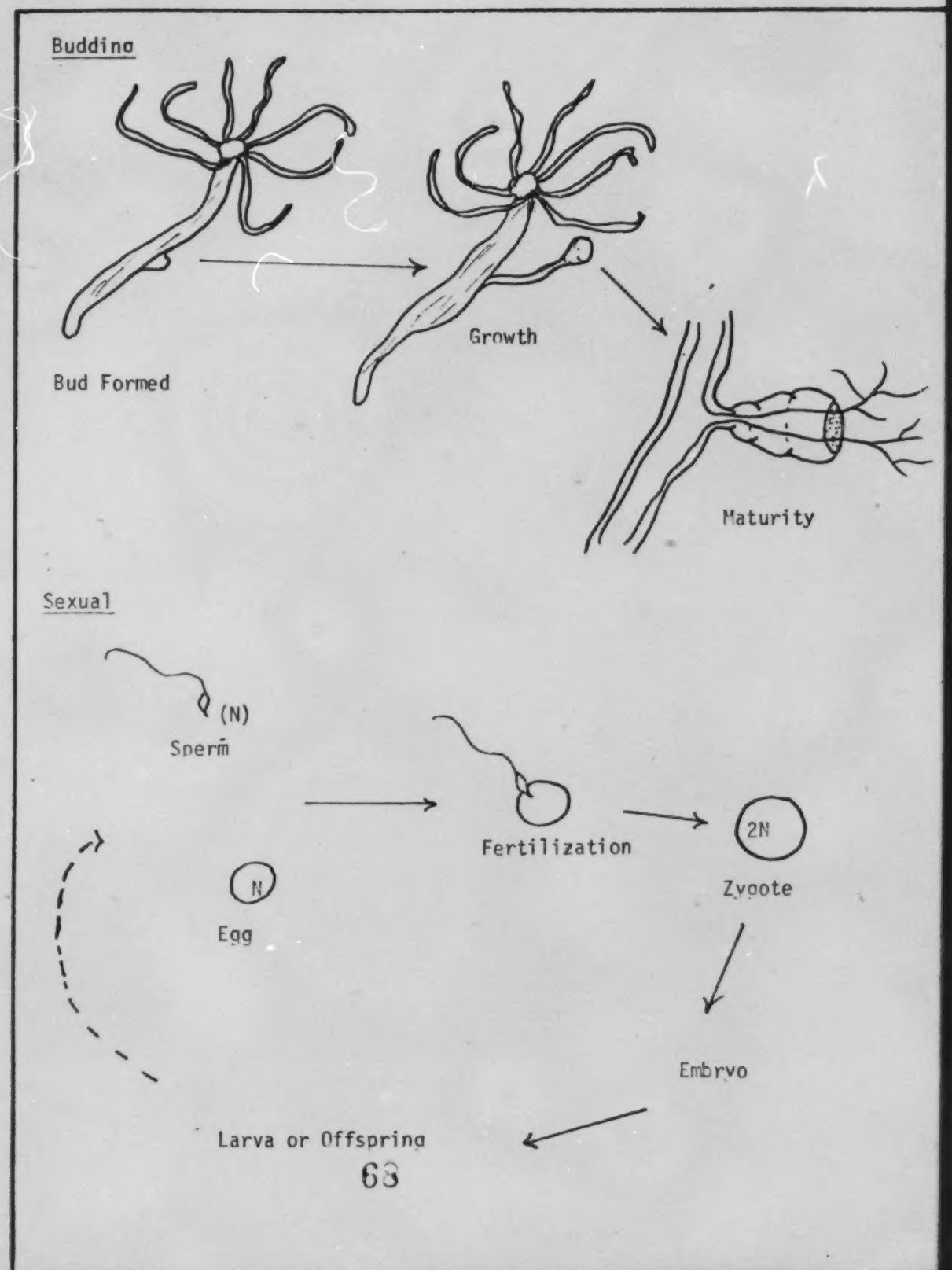
The more primitive phyla reproduce by budding, or by sexual methods yielding gametes, larva, or fertilized eggs. As the animals become more complex, the budding method of reproduction becomes less predominant and sexual methods prevail.

However, it must be noted that regeneration of missing parts randomly appears in various phyls throughout the kingdom.

Following are illustrations of a few of the variations of the sexual methods of reproduction as well as budding and regeneration.

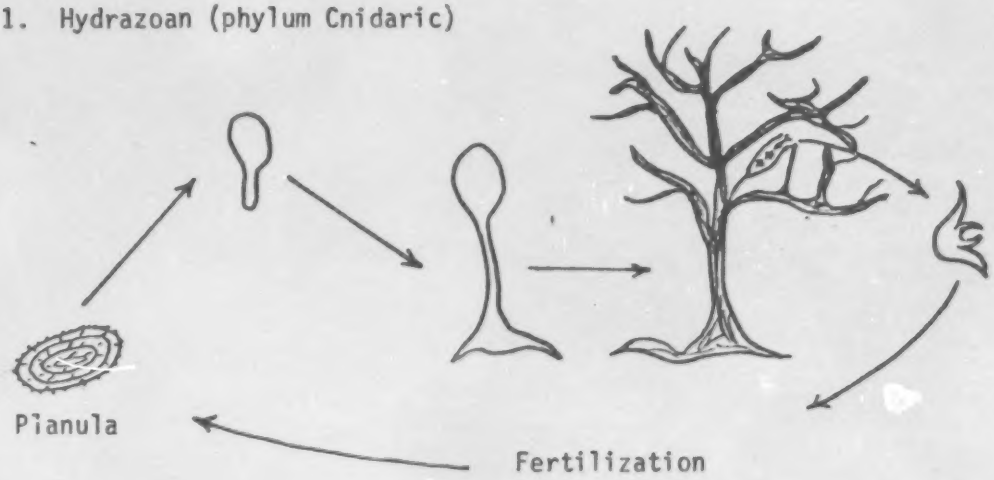
Regeneration



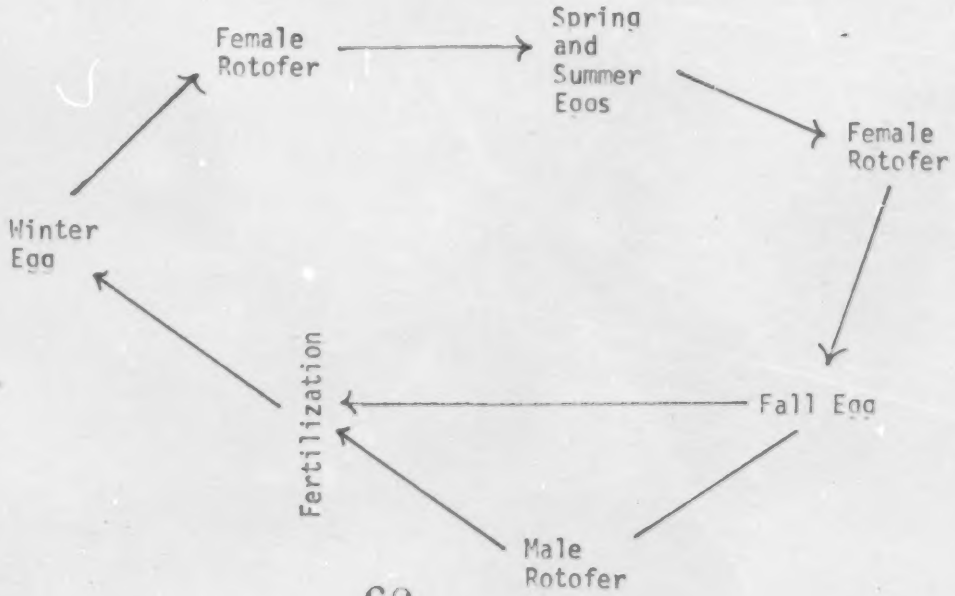

Budding
Bud Formed
Growth
Maturity
Sexual
(N)
Sperm
Fertilization
2N
Zygote
N
Egg
Embryo
Larva or Offspring

Life cycles of the members of the animal kingdom are just as varied as the reproductive patterns. In order to illustrate this, a few random life cycles are illustrated below:

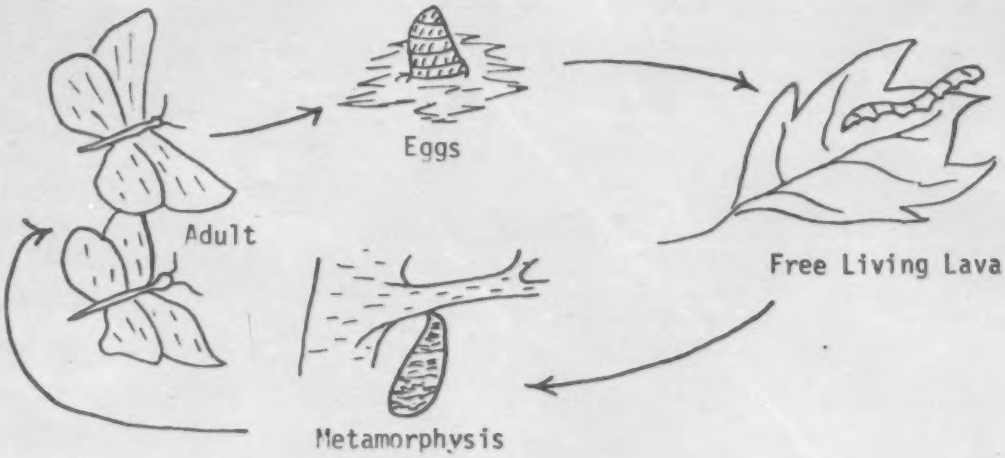
1. Hydrazoan (phylum Cnidaric)



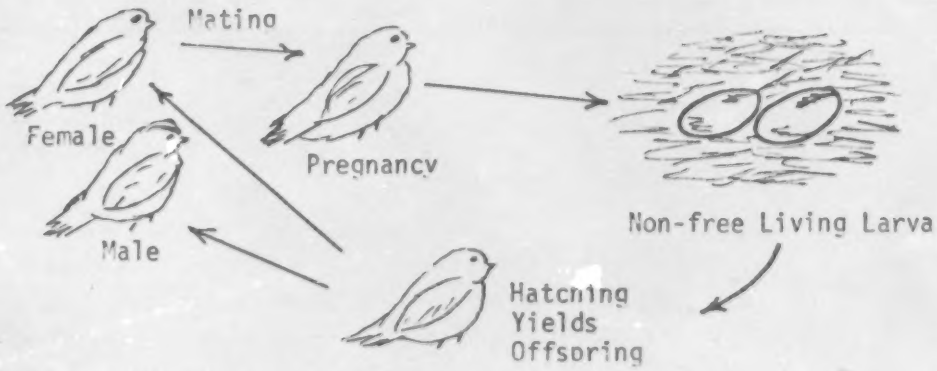
2. Rotifers (phylum Aschelminthes)



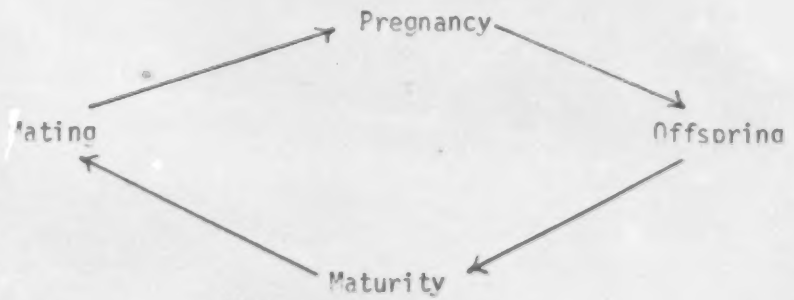
3. Butterflies (phylum Arthropoda)



4. Birds (phylum Chordate)



5. Mammals (phylum Chordata)



THE PROTISTA, MONERA & VIRUSES

As with any classification system there are organisms which "don't fit in". These organisms are just such forms. They fit into neither the plant nor animal kingdom and they don't all possess the same characteristics to form a third kingdom satisfactorily. Therefore these ancient organisms are grouped in a variety of ways and will simply be viewed here as monera (lower protista), protista and viruses.

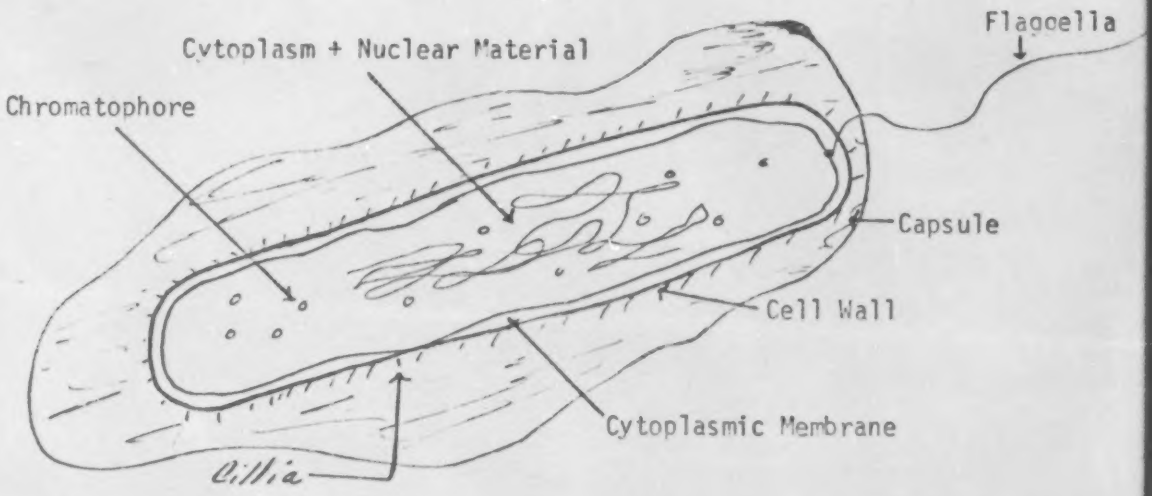
MONERA (Lower protista)

The monera are the more primitive of the two and is divided into two phyla.

Phylum Schizophyta - bacteria

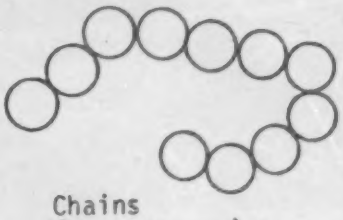
Phylum Cyanophyta - blue-green algae

Basic Cell Structures

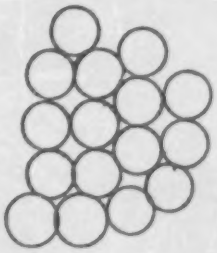


Basic Cell Forms

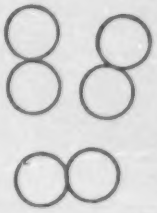
Coccus Bacteria



Chains
(Streptoccus)

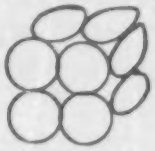


Clusters
(Staphlyococcus)



Diplococcus
(Diptheria)

Tetrads
(Tetracoccus)



Cuboidal
(Sarcinia)

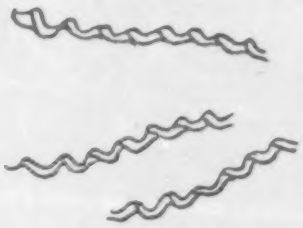
Bacilli Bacteria

(Streptobacillus)

(Bacillus) (Clostridia)

Spiral Bacteria

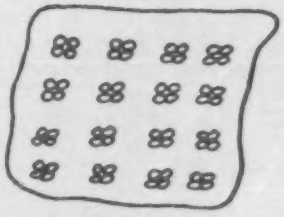
(Leptospira)



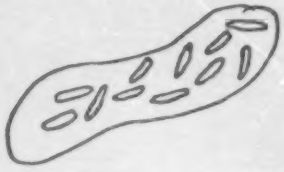
(Treponema)

Blue Green Algae

(Aphanocapsa)



(Merismopedia)



(Gleotheca)

(Spirulina)

(Phormidium)

(Nostoc)

Note the similarities to bacteria in cell arrangement and morphology.

Reproductive Patterns

The simplicity of these structures is reflected by the reproductive pattern.

Moneran cells reproduce by binary fission.

Oxygen Requirements

Oxygen requirements of moneran cells group them into four basic groups

1. Strict aerobic

2. Faculative aerobic

3. Faculative anaerobic

4. Strict anaerobic

Nutrition, Respiration, and Synthesis

Nutritional requirements as well as respiration and synthesis vary from one species to another. They do, however, follow an autotropic (plant) or hetertropic (animal) pattern depending on whether or not they are photosynthetic.

The bacteria are split between being photosynthetic or autrophic and heterotrophic. The bacteria which are autotrophic are able to use CO_2 as their sole source of carbon (like plants). These bacteria include the sulfur and iron bacteria discussed later. The heterotrophic bacteria are more animal-like and require organic carbon, essential amino acids and one or more vitamins in their diet as do animals.

The blue-green algae are in many cases pigmented red and yellow as well as blue, green and black. Since chlorophyll is present these moneran organisms are photosynthetic (autotrophe) like plants.

These single celled organisms play an important role in the environmental ecosystem. The bacteria actively aid in decay, transforming nitrogen, and transmission of disease. The blue-green algae aid in ecosystem balance and food supply since they are photosynthetic.

PROTISTA

The protista are composed of four groups which are divided into 10 phyla.

Algae

Phylum Chlorophyta - green algae

Phylum Charophyta - stoneworts

Phylum Englemophyta - euglemoids

Phylum Chrysophyta - golden brown algae

Phylum Pyrophyta - fire algae

Phylum Phaeophyta - brown algae

Phylum Rhodophyta - red algae

Fungi

Phylum Mycophyta

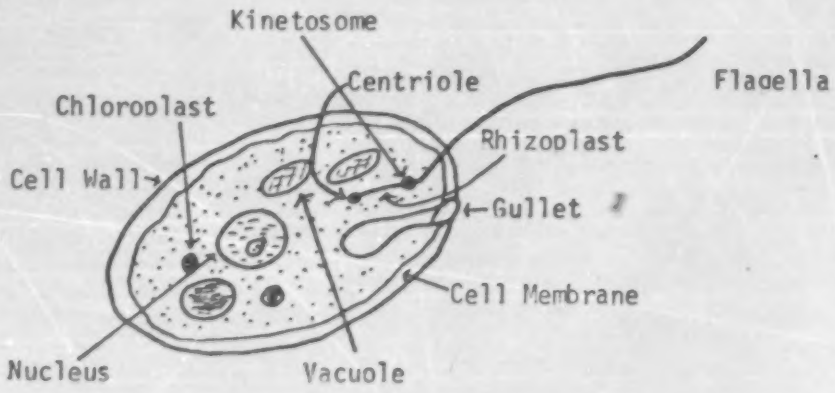
Slime Molds

Phylum Mynophyta

Protozoans

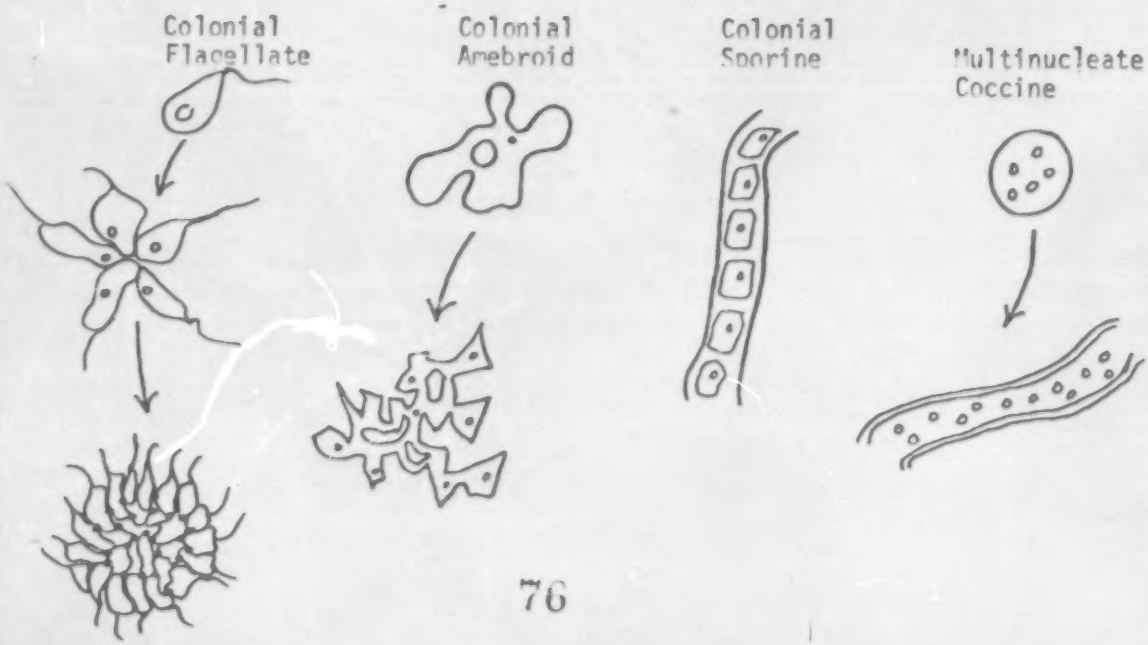
Phylum Protozoa

Basic Cell Structures

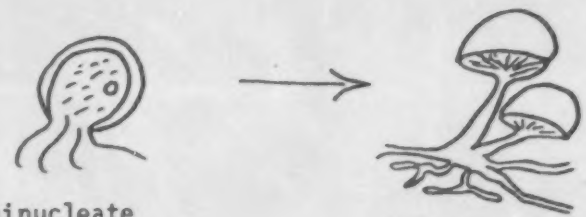


Basic Cell Forms

Algae



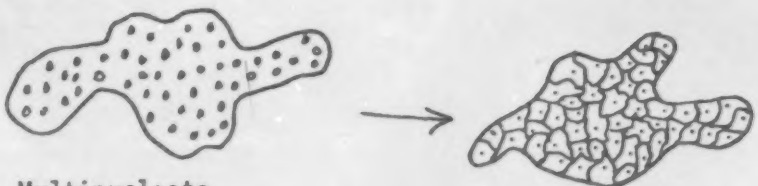
Fungi



Uninucleate Coccine

Multinucleate Coccine

Slime Mold



Multinucleate Amoeboid

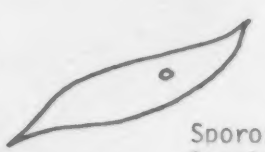
Multicellular Amoeboid

Protoza

Amoeboid

Ciliate

Flagella

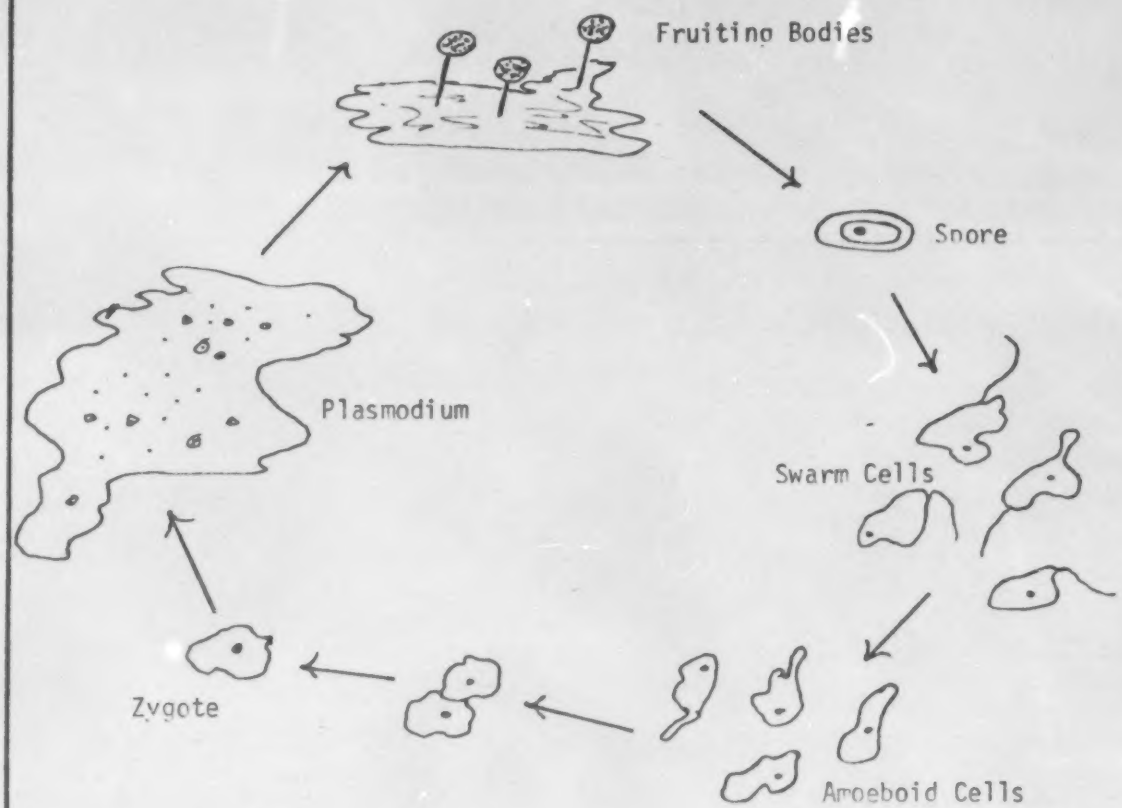


Sporozoan Coccine

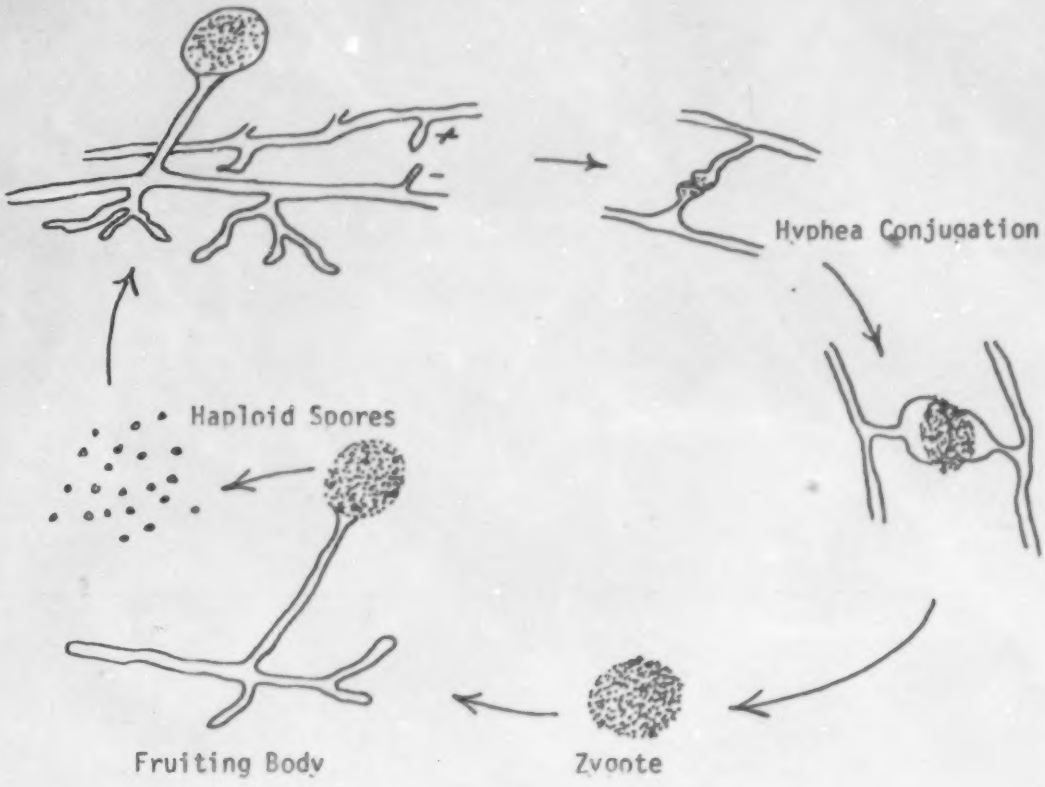
Reproductive Patterns

Reproductive patterns of the protista vary with the phyla. The seven phyla representing the algae group usually reproduce by vegetative multiplication (mitosis) if single celled. Those which are multicelled also commonly propagate by regeneration of fragments.

The slime mold's life cycle and reproductive pattern is very similar to that of a large amoeba. This is diagrammed below.



The fungi follow a pattern which is very similar to that of the slime mold and is diagrammed below.



The protozoans reproduce like the algae on the more primitive monera by asexual binary fission. This type of reproduction is prevalent regardless of whether the protozoan is amoeboid, ciliated or flagellated. The coccine or sporozoa are parasitic and lead a complex life cycle passing from one host to another.

Nutrition, Respiration, Synthesis

Like the moneran cells, the protista vary from one to another with respect to nutritional requirements, respiration and synthesis patterns. The algae are, for the most part, photosynthetic and therefore autotrophic like plants. The fungi are devoid of chlorophyl and are nutritionally heterotrophic like animals even though structurally more closely related to plants. The slime molds resemble the amoebae animals as they too are heterotrophic but the reproductive pattern is sporulation which is plant like. The protozoa are split into distinctively plant-like or animal-like groups due to the presence or absence of chlorophyll. Unlike the other protists, these cells are generally structurally and nutritionally similar to either plants or animals. Not similar to plants in one respect and animals in another.

VIRUSES

Viruses are not cellular in structure so they do not fit into cellular classification schemes. Viruses are also too small to be seen with a light microscope so their structure must be studied under considerably higher magnification. The virus uses a host cell for growth and reproduction. Without cell penetration viruses are not able to reproduce and will eventually die. Therefore, they are dependent on living cells for growth and reproduction.

BIOLOGICAL WATER SUPPLY CONCERNS

IRON AND SULFUR BACTERIA

Corrosion of water pipes can many times be related back to the bacteria present. Iron and sulfur bacteria work independently yet together to cause corrosion and incrustation of well screens, and water pipes.

Sulfur bacteria accomplish four major reactions involving sulfur.

1. They transform organic sulfur found in waste and decaying matter into sulfate. Organic sulfur $\longrightarrow SO_4$
2. They use inorganic sulfur (S, H_2S, SO_4^-) as their source of sulfur.
3. They oxidize sulfur found in reduced, inorganic forms yielding H_2SO_4.
4. They reduce the oxidized forms of sulfur to H_2S.

Of these four reactions, the first two create few problems as far as water supplies are concerned. These two reactions affect primarily the rate of decay of organic matter.

Reactions three and four, on the other hand, can create innumerable problems for the water supplier. The sulfur oxidizing bacteria create highly acidic conditions which can lead to corrosion of the pipes or screens. There are two generally recognized groups of sulfur oxidizing bacteria.

1. Thiobacillus
2. Filamentous (i.e. Thiothrix)

The thiobacillus are gram negative nonspore-forming rod shaped autotrophs. The different species of this genus are differentiated by the type of sulfur compound it uses for its energy source.

The filamentous bacteria create an additional problem in that they tend to form a film over the surface on which it grows. This can lead to clogging of well screens or pipes.

The sulfur reducing bacteria - Desulfovibrio - reduces sulfur compounds to H_2S in oxygen deficient waters. The H_2S then reacts with ferrous iron on the presence of water and creates rusting of the iron. This only occurs under anaerobic conditions, at a temperature of 10 - 30° C, and at a pH above 5.5. In a well or water pipes these conditions are easily derived if slime forming bacteria create localized anaerobic conditions.

This oxidation-reduction can be illustrated by the following:

$$S + NO_3 \xrightarrow{\text{Desulfovibrio}} SO_4 + N \text{ (gas)}$$

$$H_2O + Fe^{+2} \xrightarrow[\text{Iron Bacteria}]{} FeS + Fe(OH)_2$$

At pH values below 4.5 corrosion or oxidation of ferrous iron occurs very slowly. Iron bacteria, however, exhibit optimum growth at these low pH values and at conditions found in wells and water pipes. The three most common groups of bacteria associated with ferric iron incrustation are:

1. Thiobacillus furooxidans: These bacteria oxidize ferrious iron to ferric iron during its normal growth cycle when grown at pH 2.4 to 3.5. The ferric iron is then deposited into the water from where it can lead to incrustation of the water well screen or water pipe.

2. Clonothrix, Crenothrix, Lystothrix: These filamentous bacteria create an iron incrusted sheath from which the cells grow. In this case the bacteria themselves can create an incrustation problem on well screens or in water pipes.
3. Gallionella Ferruginea and Metallogenium: These are stalked iron bacteria which secrete iron in the form of ferric hydroxide filaments. These filaments, like the leptothrix, can create incrustation problems simply by their pr[illegible]e [illegible]d growth around well screens and in water pipes. Diagrams of thes[illegible] bacteria follow.

Thiobacillus

Filamentous Bacteria

Gallionella

Treatment and control measures for incrustation by iron, sulfur and slim-forming bacteria are limited. Presentation of introduction of these bacteria into a well through the drilling equipment is the best control measure. When a bacterial incrustation problem is diagnosed, however, an effective maintenance program must be established. Periodic chlorination or cleaning with quaternary ammonium compounds will help prevent this type of incrustation of well screens and surrounding ground water formations. In piped ground water systems continuous chlorination is the best currently available measure to prevent iron bacteria incrustation in water pipes.

ALGAE

Algae in Water Supplies
U. S. Dept. of HEW
Public Health Service Publication No. 657

Algae Significance

Algae are common and normal inhabitants of surface waters and are encountered in every water supply that is exposed to sunlight. While a few of the algae are found in soil, and on surfaces exposed to air, the great majority of them are truly aquatic and grow submerged in the waters of ponds, lakes, reservoirs, streams and oceans. By operators of water treatment plants the algae are best known for their ability to produce odors and tastes and to clog sand filters. In addition, they have come to be recognized as important in the water supply in many other ways, including their capacity for modifying the pH, alkalinity, color, turbidity, and lately the

radioactivity of water. Some are undoubtedly the most troublesome of the various types of nuisance organisms, but others can actually be put to good use in improving a water supply.

Taste and Odor Algae

One of the requirements in the production of potable water for modern communities is that the product shall be free of obnoxious and abnormal tastes and odors. Of the several causes of these tastes and odors, the algae present in the raw water supply are recognized as being either the primary, or at least one of the most important.

Some of the algae produce an "aromatic" odor which is described more specifically for certain organisms as that resembling a particular flower or vegetable. Common examples of these would be geranium, nasturtium, violet, muskmelon, and cucumber. In some cases it is described as an attractive spicy odor, but in others it may be very objectionable, as for example a skunk or garlic odor. Some pigmented flagellates and diatoms produce the aromatic odors when these organisms are present in small numbers in the water.

A second type of odor, the "fishy" odor, is produced often by the same algae that are responsible for the aromatic odors. The organisms generally are present in much larger numbers when the fishy odor is evident. More specific terms that have been used to describe the fishy odors of various algae are clam-shell, cod liver oil, sea weed, Irish moss, rock weed, and salt marsh. The differences between these are probably insignificant in water supply studies.

Synura is one of the more potent algae in production of an odor in water which is often described as resembling that of a ripe cucumber or muskmelon. A comparatively few colonies per ml may be sufficient to cause a very perceptible odor. This organism also produces a bitter taste in the water and leaves a persistent dry metallic sensation on the tongue. When present in large numbers, this, as well as other flagellates, may develop a fishy odor.

A third type of odor is the somewhat aromatic one which is described as "grassy". It is the most common one produced by green algae and generally is apparent only when the organisms are present in large numbers. It is reported also for certain blue green algae and occasionally for diatoms and pigmented flagellates.

The fourth type of odor is the one which includes those described as "musty" and "earthy". The latter is commonly associated with actinomycetes and with a few algae. It can vary from mild to decidedly pungent. The earthy odor of soil also has been considered to be due to the presence of actinomycetes. The very common musty odor in water is encountered in the presence of certain blue-green algae and a few other forms. It has been described by additional terms such as potato bin and moldy. Some waters have been reported as having weedy, swampy, marshy, peaty, straw-like and woody odors and these are possibly a modification or a combination of the grassy and musty odors.

A septic color has been associated frequently with the presence of large accumulations of blue green algae and occasionally of the green algae, Hydrodictyon and Cladophora. Other names applied to this type of odor are pigpen, foul, objectionable, vile, fermentatio and putrefactive.

As these terms suggest, it is produced as a result of the decomposition of masses of algae, especially where a lack of sufficient oxygen permits the formation of odoriferous intermediate products from the algal proteins.

Chlorophenolic, iodoform, or medicinal odors may be produced by the action of chlorine on the products of certain algae although somewhat similar odors may be present in the water at other times because of industrial wastes.

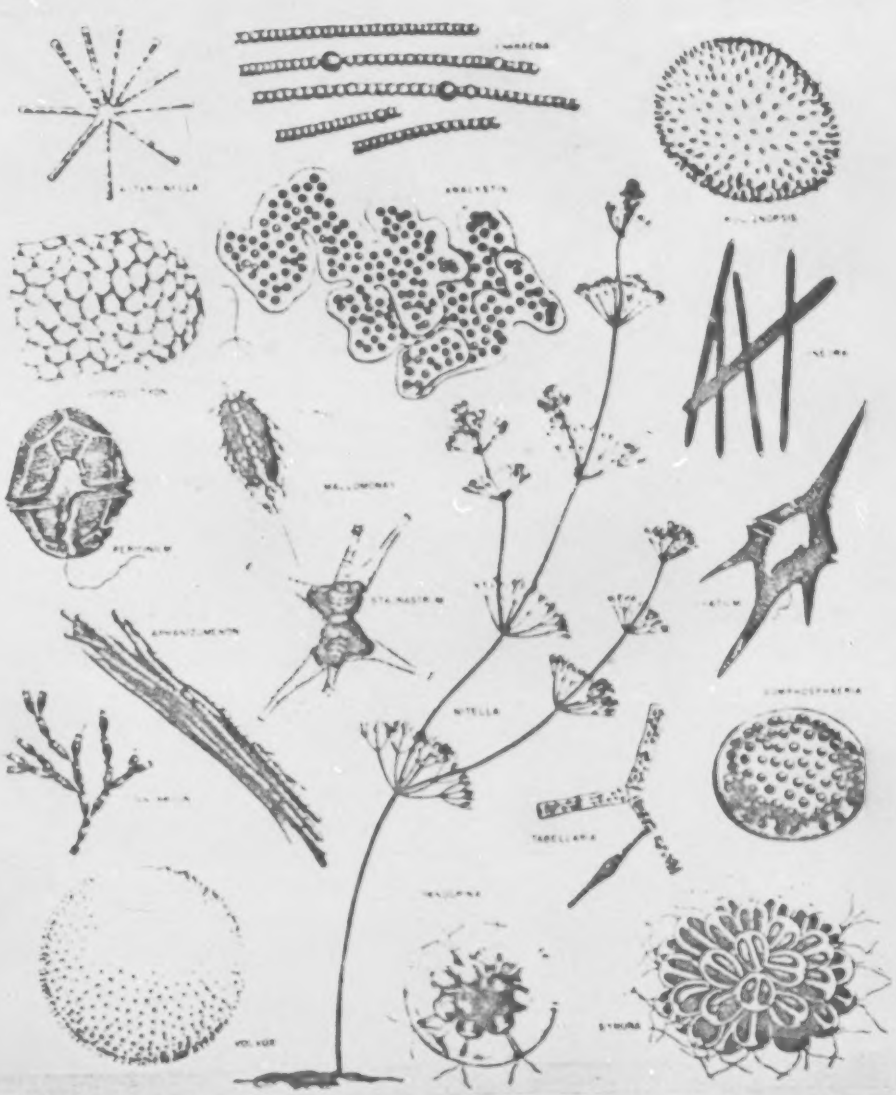
Asterionella is considered one of the worst offenders among the diatoms, having a characteristic aromatic geranium like odor that changes to fishy when the alga is present in large numbers. Tabellaria produces a similar effect while Synedra has an earthy to musty odor and Stephanodious is blamed for a "vegetable to oily taste" with very little odor.

Certain blue green algae are well known for developing very foul "pigpen" odors in water. Three of these algae are Anabaena, Anacystis (formerly Aphanizomenon. All of these are capable of collecting in large masses sufficient to form water "blooms". The foul odor undoubtedly develops from products of decomposition as the algae begin to die off in large numbers. These same blue green

algae together with others such as Gomphosphaeria (which now includes Coeloxphaerium), Cylindrospermium, and Regularia have a natural odor which is commonly described as "grassy". This often changes to the odor of nasturtium stems, probably as a result of oxidation.

Green algae are less often associated with tastes and odors in water. In fact, their growth may help to keep in check the blue green algae and the diatoms and thus be a positive factor in the control of water quality. However, Hydrodictyon (water net), the desmid, Staurastrum, and the large massive stone warts , Nitella and Chara, may offend rather than help in this biological competition between types. Dictyosphaerium is regarded as one of the worst offenders among the green algae, giving a fishy as well as a grassy to nasturtium odor. Some of the swimming green algae which are listed with the flagellates, including Volvox, Pandorina, and Chlamydomonas, are able to produce fishy odors.

TASTE AND ODOR ALGAE



Filter Clogging Algae

As water passes through a sand filter in the treatment plant the spaces between the grains of sand become filled with colloidal and solid particles which had been dispersed in the water. If the raw water comes from a surface supply such as a reservoir, lake, or stream, the algae which are invariably present will be well represented in the material collected by the sand filter. They are frequently the primary causes for the clogging of the filter.

Both the slow and rapid sand filters may become clogged with algae, but in the former the algae and other aquatic microorganisms may play a useful part in the treatment process. They form a loose, slimy layer over the surface of the sand and act as a filter. The algae in this layer release oxygen during photosynthesis, and the oxygen in turn is utilized by aerobic saprophytic bacteria, fungi and protozoa which establish themselves in and on the filter. This permits the decomposition or stabilization of the organic material that was present in the raw water. Diatoms, however, due to their rigid walls, may do more harm than good by speeding the clogging of the filter, but it has been possible to use slow sand filters when diatoms have put rapid filters out of commission. The water that has passed through a slow sand filter is relatively free of bacteria, algae, and other organisms as well as of dead organic matter.

It is not yet fully understood why certain algae are more effective than others in reducing the movement of water through the filters. Ability to develop in large numbers is certainly one essential.

The rigid wall, such as is found in the diatoms, the copious mucilaginous material around the cells as in the case of Palmella, and the tendency to form flakes or a network of strands, as in Fragilaria and Tribonema are other factors.

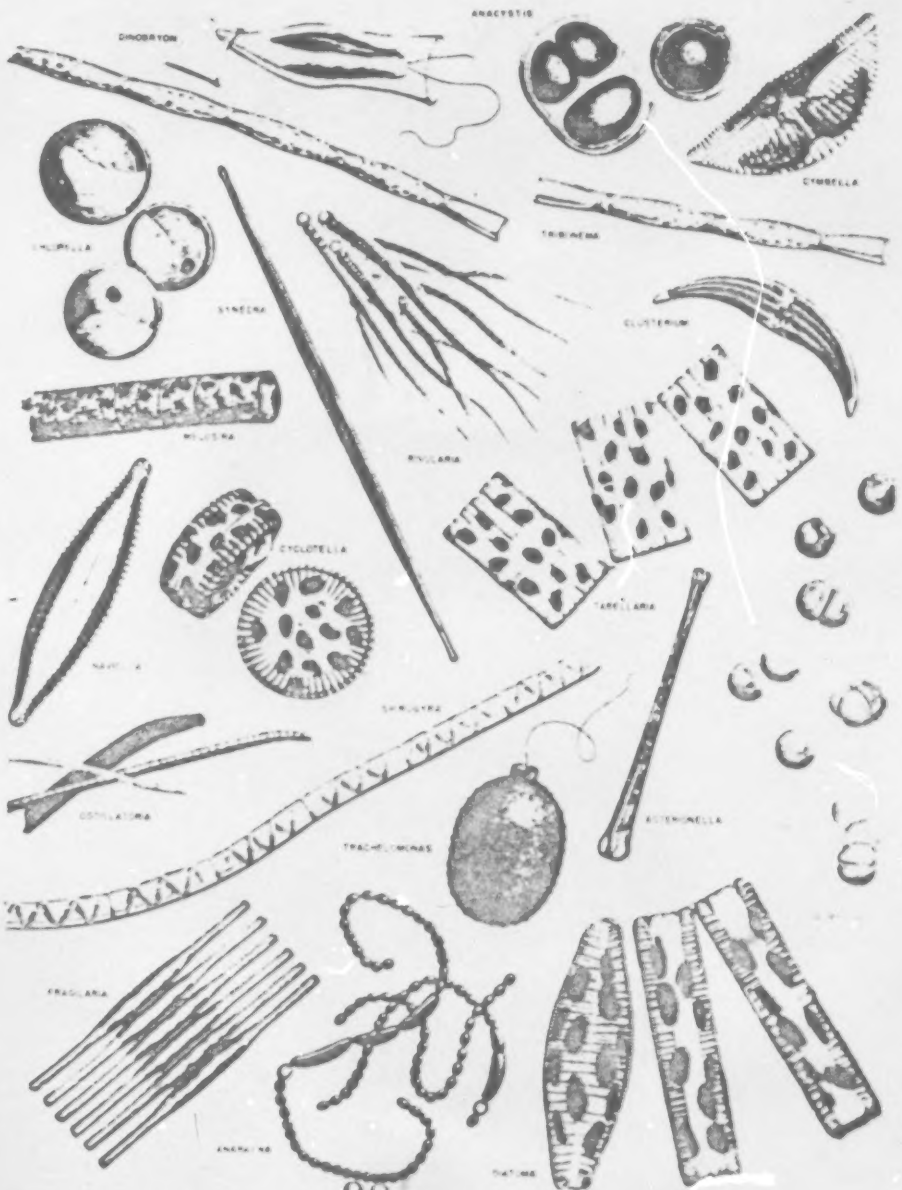
Diatoms are present during all seasons of the year and are by far the most important group of organisms which clog filters. The most, serious offenders are Asterionella, Fragilaria, Tabellaria, and Synedra. Other diatoms that may occasionally cause this trouble include Naricula, Cyclotella, Diatoma, and Cymbella.

The rigid cell wall of diatoms is composed principally of silica and is not subject to decomposition. Therefore, even though the diatoms may die off rapidly on the surface of the filter, their silica walls remain to plug the pores in the sand.

The filter clogging blue green algae are represented by Anacystis (Chroococcux type), Rivularia, Anabaena and three species of Oscillatoria. Anabaena is known to have caused filter trouble in Illinois and Minnesota while Oscillatoria is one of the offenders in Switzerland. Dinobryon and Traehelomonas are pigmented flagellates the former being common in the Great Lakes and in the soft waters of the eastern United States. Chlorella, Palmella, Sporogyra and the desmid. Closterium, are green algae while Tribonema is a yellow green filament. Chlorella is the alga which has given trouble by clogging filters made of glass wool. In addition, it grows on the inner surfaces of the glass bottle in water coolers and in water lines constructed of plastic tubing, when these have been exposed to light.

In the tropics and warm temperate zone, the filamentous green algae are often the common offenders in clogging of sand filters.

FILTER CLOGGING ALGAE



Other Algae Related Problems

Slime

Algal slime commonly is derived from the mucilaginous capsule or sheath which envelops the cells. The blue green algae as a group are notorious slime producers. Their technical name, Myxophyceae, contains the prefix "myxo" which means slime or mucus. Several diatoms as well as green and red algae and a few flagellates also produce slimy sheaths or capsules.

Coloration

Algal coloration of finished water is most frequent in communities that have uncovered storage reservoirs in the distribution system, or where the treatment of the raw water supply is not efficient in reducing the numbers of phytoplankton present. Almost any small alga capable of rapid multiplication could be involved. Complaints come from patrons when the water from the faucet is colored, or when a colored marginal ring forms at the surface of the water in the tumbler or bathtub. Colors ranging from yellow green through gree, blue green, red, and brown to black could all be due to algae. However colors in water may also be caused by substances other than algae.

Corrosion

Typical algae are unlikely to be the direct cause of corrosion of iron or steel pipes in a distribution system because most are incapable of active growth in the absence of light. However, algae have been reported to cause corrosion in metal tanks or basins open

to sunlight.

Indirectly, algae may affect the rate of corrosion in a number of ways. Increase in organic deposits in the pipe, increase in the dissolved oxygen in the water through photosynthesis in the raw water supply, and changes in the pH, CO_2 content, and calcium carbonate content of the water can all be brought about by algae. These changes can, in turn, affect the rate of corrosion. Iron and sulfur bacteria may have a more direct relationship to corrosion and may be significant particularly on the outside surfaces of pipe buried in the ground.

Algae Blooms

A number of the surface water algae have the ability to accumulate, at times, in such numbers as to form loose, visible aggregations called "blooms", which may cover very large areas of lakes and reservoirs or even streams. Blue green algae may form these water blooms particularly during periods of warm, calm weather, when the algae which previously were distributed through the water rise to the surface. Other blooms may be associated with a rapid reproduction of a particular alga. Some water blooms have resulted in fish kills by interfering with reaeration, by excluding light necessary for photosynthesis in the lower areas and thereby preventing release of oxygen into the water, or by depleting the oxygen through decay or respiration within the bloom. Some water blooms release substances extremely toxic to fish, domestic animals, and birds, and extensive kills have resulted in several areas.

A considerable number of species of algae are capable of producing blooms. Some of the genera most frequently involved are

the blue green algae, Anacystis (Microcystis), Anabaena, Aphanizomenon, and Oscillatoria; the green algae, Hydrodictyon, Chlorella, and Ankistrodesmus, the diatoms, Synedra and Cyclotella; and the flagellates Synura, Euglena, and Chlamydomonas. Blooms of blue green algae are particularly obnoxious. Blooms of flagellates and green algae are often encouraged by the addition of fertilizer in farm hatchery ponds in order to increase fish production.

Related to the blooms, are the "mats" or "blankets" of filamentous green algae such as Spirogyra, Zygnema, Oedogonium, and Cladophora which at times may cover large areas of a reservoir or lake. Certain blue green algae, such as Gloeotrichia natans may also form extensive floating masses. These growths cause an unsightly appearance in a community's water supply and serve as breeding places for gnats and midge flies. They may clog intake screens, cause tastes and odors, and interfere with the functioning of multiple purpose reservoirs by collecting as debris on the shores and interfering with fishing and bathing.

Control of Algae

Control of algae in water supplies thus may involve the use of algicides; the mechanical cleaning of settling basins, filters, intake channels, and reservoir margins; the modification of coagulation, filtration, chemical treatment or location of the raw water intake; and, finally, the modification of the reservoir to reduce the opportunities for massive growths. Control of tastes and odors and other algal products involves additional procedures such as the use of absorbents and the removal of organic deposits from settling basins

and distribution lines. Effective control of algae is dependent upon adequate procedures for detecting their presence and interpreting the significance of any change in their numbers and kinds.

PATHOGENS

Water is a potential carrier for pathogenic (disease causing) bacteria and other microorganisms. Some of the more renown are the salmonella which cause typhoid fever, and enteritus, shigella which causes dysentery, and vibrio comma which causes cholera. These organisms are diagrammed below.

Salmonella Shigella Vibrio Comma

Viruses causing diseases such as infectious hepatitus and polio can also be transmitted by water not to mention the protozoa Entamoeba histolytica which causes amoebic dysentery.

These and many of the other pathogenic microorganisms are discharged by infected person in the fecal matter. Since stream which is used for wastewater effluent discharge may also be used for potable water

supply downstream, the possibility of disease transmission is evident.

Proper water treatment is therefore essential. Since bacteria are much too small to routinely eliminate by filtration or other removal methods, distruction of th pathogens in the treatment process (disinfection) is the accepted method of eliminating this potential hazard.

The least expensive and most readily available disinfectant and therefore most commonly used, it effectively destroys the pathogens and maintains a chlorine residue for a period of time to aid in protection from in line areas of contaminant entrance if any exist.

Another excellent disinfectant is ozone. Even though it is tasteless, odorless and easy to produce, it is more expensive than chlorine and leaves no residue for inline protection. Therefore it is not yet in wide use.

Ground water though not as susceptable as surface water to pathogen contamination, must also be examined. New wells have frequently been contaminated with salmonella causing diseases ranging from acute gasteroenteritus to typhoid fever. Seepage from septic tanks on animal lots can enter the groundwater leading to contamination also. Therefore, location of the well and proper abandonment methods are also essential preventative measures.

Detection of pathogens by laboratory procedures takes much too long for routine use since by the time they would be identified the disease would already be spreading. Indicator organisms, one always excreted with the pathogen in fecal matter is used. For this reason coliforms are used to indicate possible presence of diseased organisms.

BIOLOGICAL WASTEWATER CONCERNS

RAW WASTEWATER

Composition: Since the potable water supply of many cities is drawn from surface waters, these waters must be protected. These same surface waters, however, may also serve as receiving streams for wastewater. This wastewater disposal is of biological concern not only because it is a potential source for rapid spread of disease but also most treatment procedures rely on biological activity for degradation of organic and inorganic pollutants.

The biology of domestic wastewater differs from that from industry. Domestic wastewater is composed of primarily human excreta and wash waters. Industrial wastewaters on the other hand, may contain high concentrations of chemicals, greases, and oils, or organic matter. These substances can be described as matter which can be used as food for the microorganisms as they degrade the wastes. The poisonous substances, however, tend to prevent the microbial action and thereby prevent biological breaking down of the organic waste material.

Disease Transmission: The primary concern with wastewater is its ability to transmit disease. Not only diseases which are caused by bacteria, but the viral and protozoa mediated diseases are also important. These organisms are usually inactivated during waste treatment. If the organisms survive undamaged, they can create a health hazard when released into the receiving stream.

Salmonella is one of the most varied group of pathogens

for man. This organism can cause a variety of enteric fevers and gastro-intestinal illnesses. One prototype is Salmonella paratyphi which causes a simple case of gasteroenteritus. Another is Salmonella typhosa, which causes typhoid fever. These two as well as many other infections are acquired through injestion of contaminated food or water. While infected people excrete millions of Salmonella along with the normal flora of their waste material, about 3% of these people then continue to harbor this organism without getting re-infected. This 3% are termed carriers. Carriers then continue to excrete this organism for the rest of their lives. The Salmonella excreted, whether from carriers or infected persons, transmit the disease.

Shigella, another bacterial pathogen transmitted in contaminated food and water can cause bacterial dysentary when injested. Again, the major source of contaminating material is the feces of infected persons.

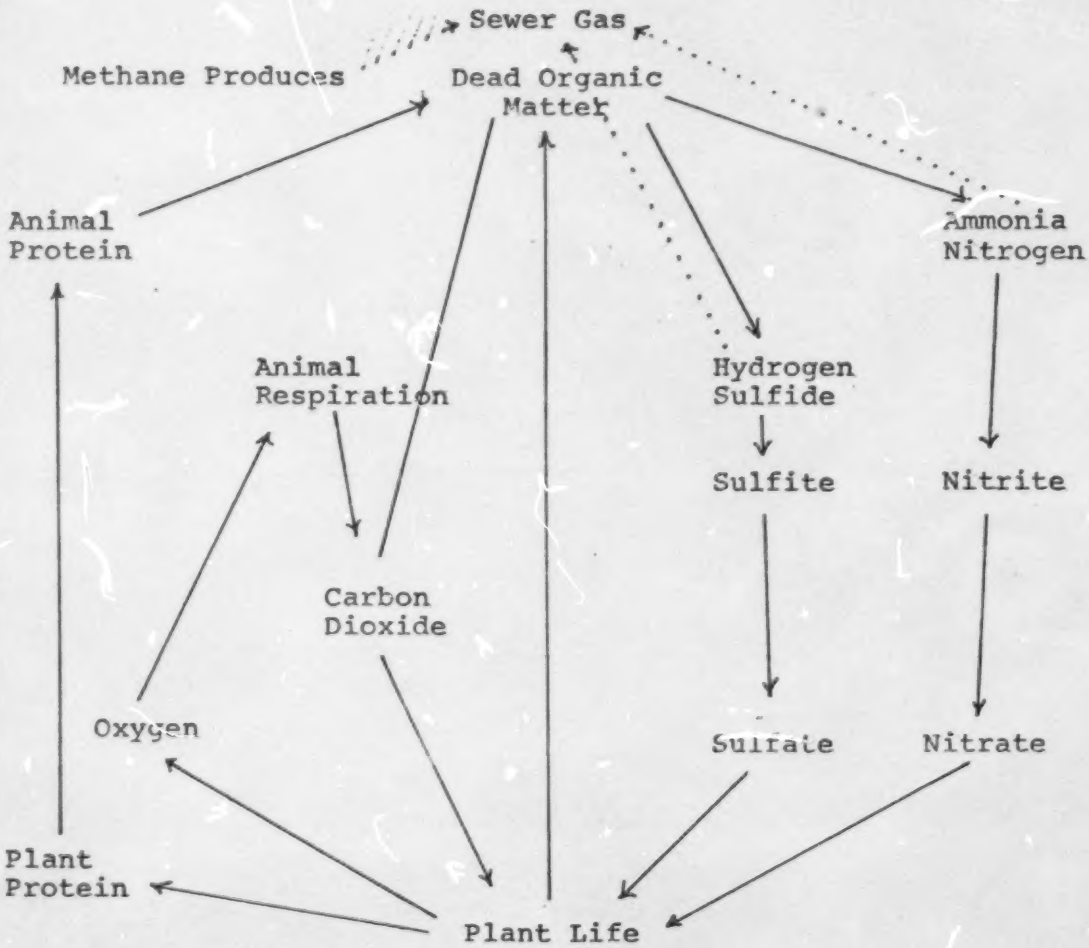
Vibrio comma, a third example, is a comma shaped bacteria which causes cholera. This is a disease which is endemic in many parts of the world due to poor or non-existant waste treatment.

In addition to bacterial diseases, many viruses which cause disease are transmitted in human wastes. Many mild intestinal disorders as well as polio fall into this caregory.

Protozoa such as Entamoeba Histolytica can survive as cysts as long as six months in nature. If infested water is injested amoebic dysentery will result.

Not only these, but also worm infestation of the intestine can be spread through water contaminated with infected feces.

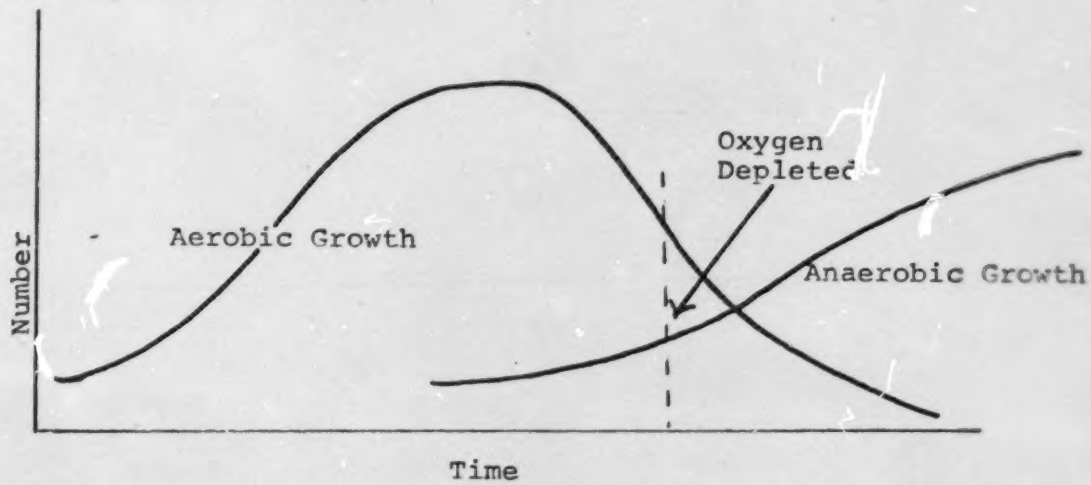
Natural Decomposition: Natural decomposition of organic waste material is continuous and fundamental to nature. Decomposition not only removes organic wastes but in doing so releases essential nutrients and stimulates further growth of organisms. This recycling can be more easily viewed by the following diagram:



This balance of natural decomposition easily becomes upset when waste material becomes concentrated and natural bacterial populations cannot quickly break it down. This concentration is easily visualized in both urban (people) and rural (animal feed lots) situations.

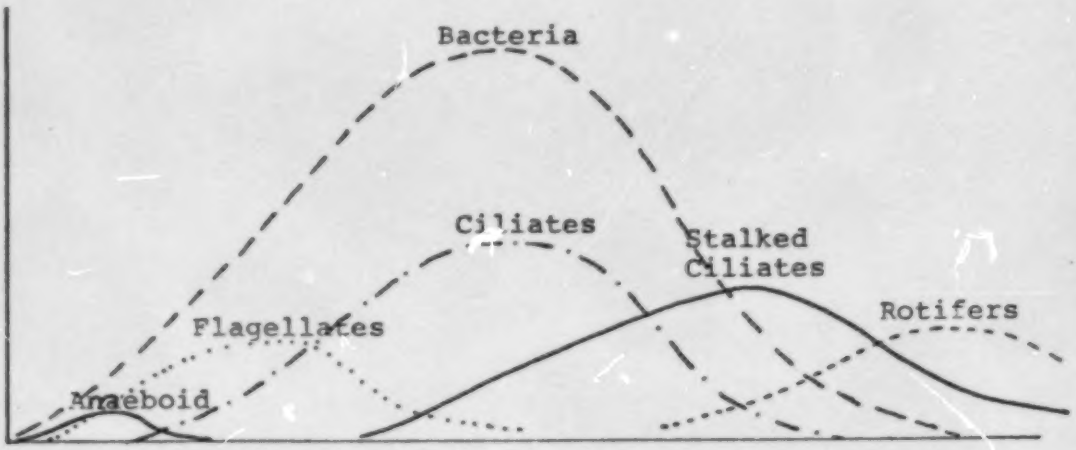
Population Dynamics

In the natural decomposition of organic matter the bacteria are the "work horses". As the available oxygen (dissolved oxygen) begins to deplete, the bacterial populations changes from aerobic to anaerobic. These anaerobic organisms therefore finish the job the aerobes start. Diagrammatically this can be shown by the following:

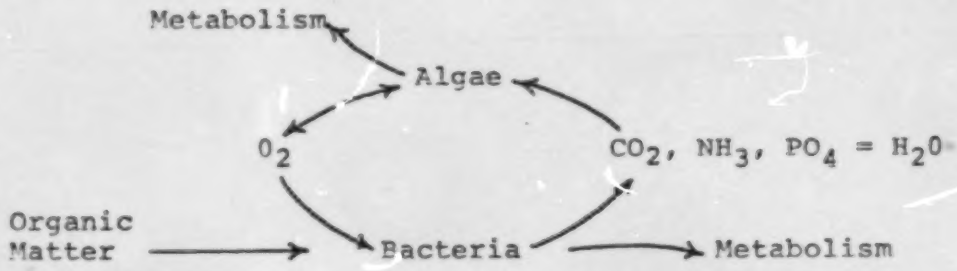


The type of food present in this organic matter plays a big role in the type of bacteria present. Carbohydrates, organic acid, aldehydes, and ketones will enhance Pseudomonas, Micrococcus, Bacillus, and Acheomobacteria growth and proteinatious material, Alcaligenes and Flavobacterium. These are the aerobic

bacteria, the ones which require oxygen, and are responsible for the majority of the natural stabilization of organic wastes. The growth of these bacteria then in turn stimulates the growth of higher organisms, i.e. protozoa and animals. This can be shown by the following diagram:

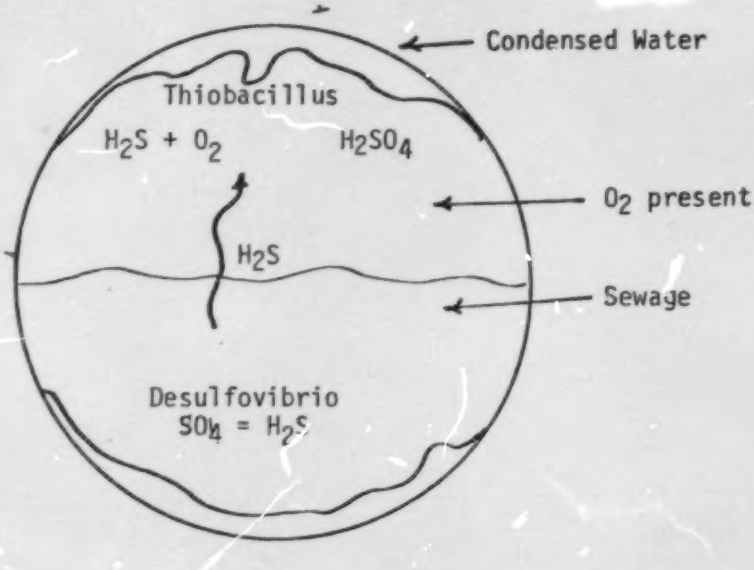


If the waste is deposited in an aquatic environment, algae also play a definite role in degradation as shown below:



Treatment processes are methods by which these natural decomposition processes can be mechanically manipulated by man to enhance the viological action. Concentrated waste matter can then be quickly and efficiently broken down.

Sewage Collection: Before the sewage can be treated it must be collected. During its flow enroute to the treatment plant the natural decomposition process begins. Due to the limited supply of oxygen conditions can become anaerobic. This leads to decomposition by anaerobic bacteria with the associated odors and corrosion problems.



PRIMARY TREATMENT

Since wastewater contains inorganic material as well as organic, the inorganics are removed prior to primary treatment. Large items are screened out and the inorganic grot (sand and gravel) allowed to settle out. This is done to save wear on pumps since the biological actions of the other processes do not break down such inorganics. Primary treatment is purely a physical process where the settleable organic and remaining inorganic solids are removed.

These settleable solis are highly biologically active and they are disposed of by digestion. The effluent contains

the non settleable solids and is also biologically active. It is this activity that forms the basis for the secondary treatment processes such as activated sludge and trickling filters. If it is discharged it must be disinfected to destroy the disease causing organisms. The natural population in the receiving stream then completes the decomposition process of the organic matter not settled out.

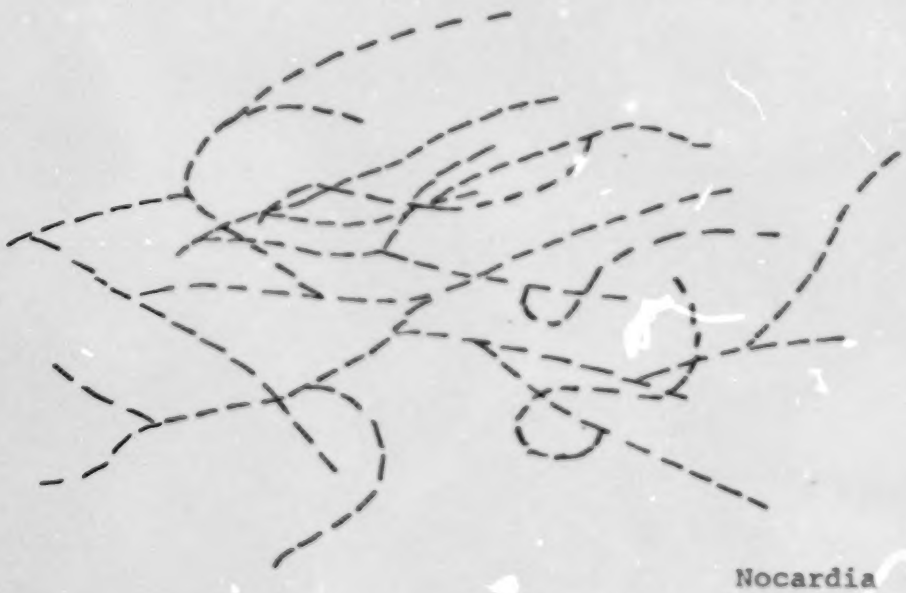
ACTIVATED SLUDGE

Activated sludge is purely biological in action. It is also designed to enhance the growth of the aerobic organisms. As the organic matter enters the activated sludge system it represents a variety of substances for the bacteria to use as food. Even though the bacteria do the majority of the "work" in breaking down the organic matter, many other organisms are present. These include the fungi, protozoa, and small animals.

The bacterial population will be determined by the type of waste material present. For example, proteinaceous waste stimulates the growth of Alcaligenes, Flavobacterium, and Bacillus where carbohydrate rich waste favors Pseudomonas, Micrococcus, Corynebacterium and Mycobacterium. These bacteria use the waste material as food for metabolism and synthesis. In order for the food to be absorbed by the bacteria it is first broken down by extracellular enzymes excreted by the bacteria. This creates compounds which are water soluble and can be absorbed by the bacteria. As the bacteria "grow" they multiply in numbers. The bacteria excrete a polymer slime layer which helps the bacteria clump together forming aggregates. As particles of

undissolved waste material attach to this slimy bacterial aggregates, flocs form and settling occurs. Too much or too little of this polymer will prevent floc formation.

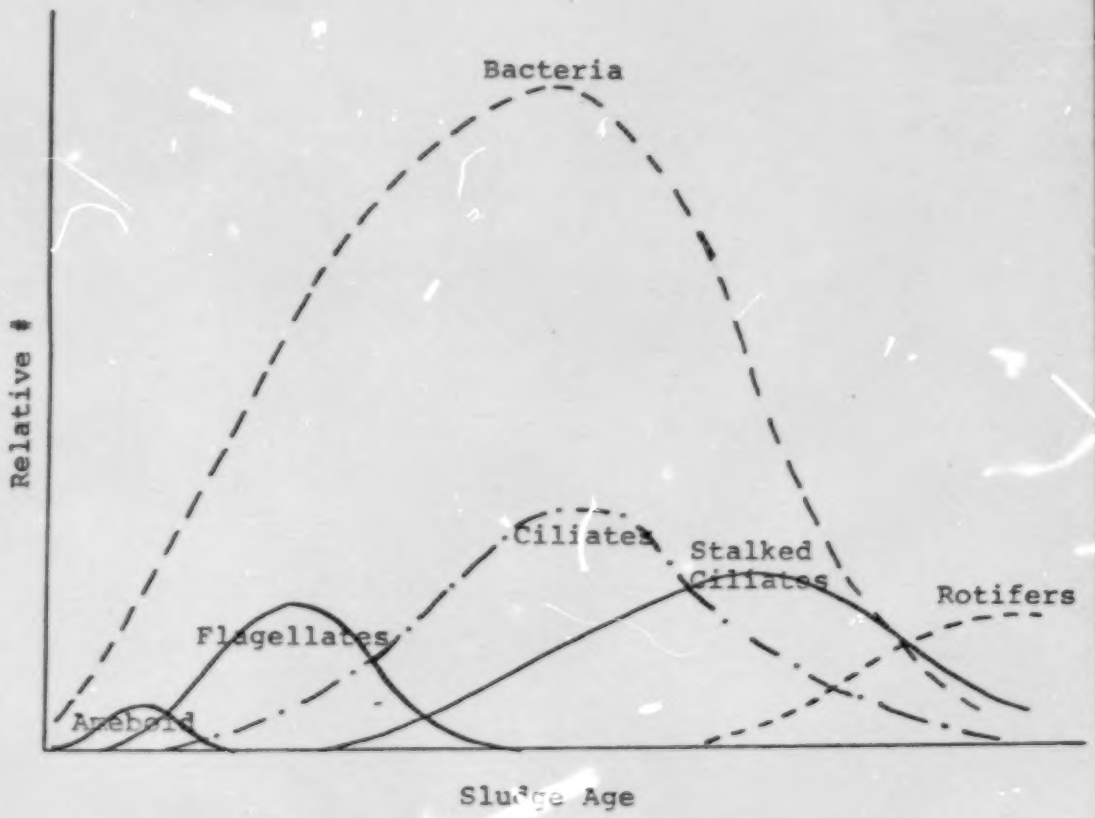
Fungi does little to help break down and stabilize waste material. Fungi is always present in activated sludge, but bacterial growth normally overrides the fungi growth. Conditions which repress the bacterial growth, i.e. nutritional deficiencies, will tend to stimulate the growth of the fungi. This is primarily due to the decrease in competition. One fungi which is often noted in upset activated sludge systems is Norcardia. This fungi and others will prevent good floc formation because of their filamentous structure.



Nocardia

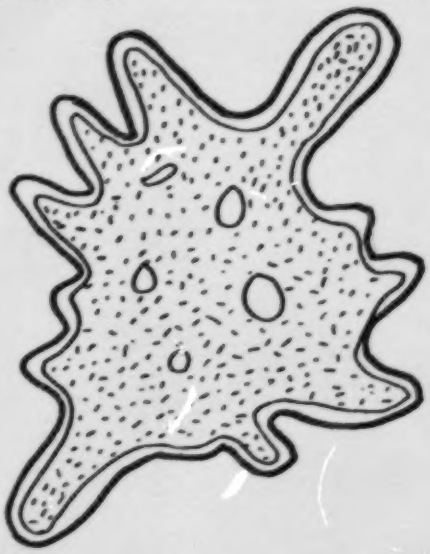
The protozoa do not contribute directly to the stabilization of the waste since the concentration of food is too low. Rather

they use the "free" bacteria (those not yet in aggregates) as their major source of food. Therefore, the protozoa population is directly related to the bacterial growth. This can be shown by the following diagram:



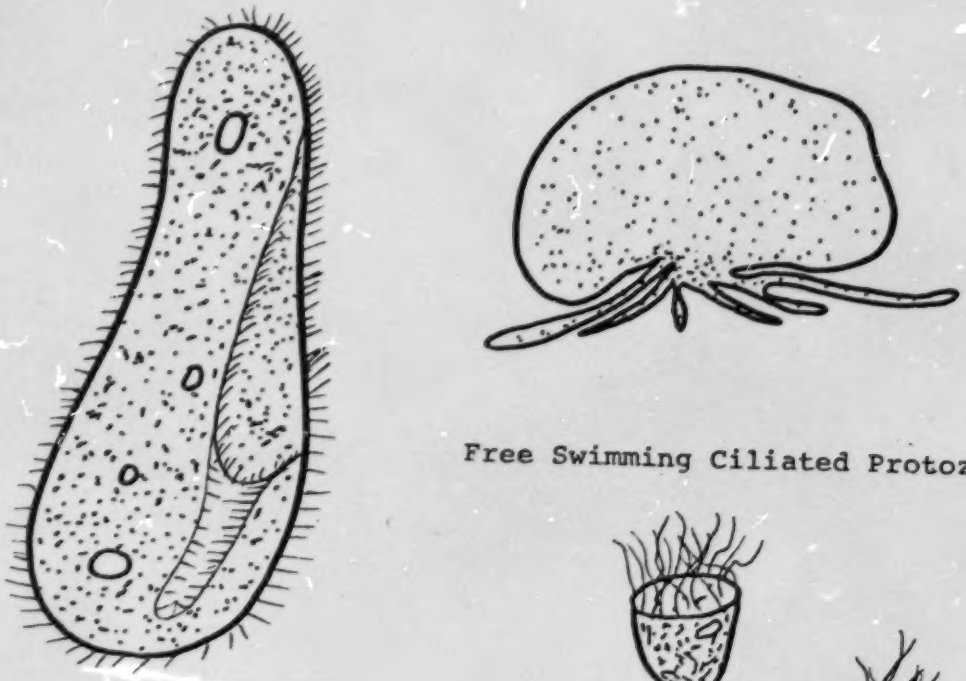
The diagram indicates that predominant protozoan population changes with the age of the activated sludge. This is easily understood if the energy requirements of the protozoa are examined. The amoeboid and the plant-like flagellated protozoa must compete with the bacteria for food. This competition always favors the bacterial growth. The more animal-like

flagellates protozoa, the free swimming cilliates, and the stalked cilliates use the free bacteria for food. Therefore, as long as the bacterial growth is maximized these protozoa thrive. However, the animal-like flagellated protozoa are not as efficient as the ciliates in obtaining the bacteria for food; therefore, the ciliates tend to predominate. As the bacterial population decreases the energy requirements of the free swimming ciliates cannot be met. At this time the stalked ciliate population predominates. This is because they require less energy for growth and metabolism than the free swimming ciliates.

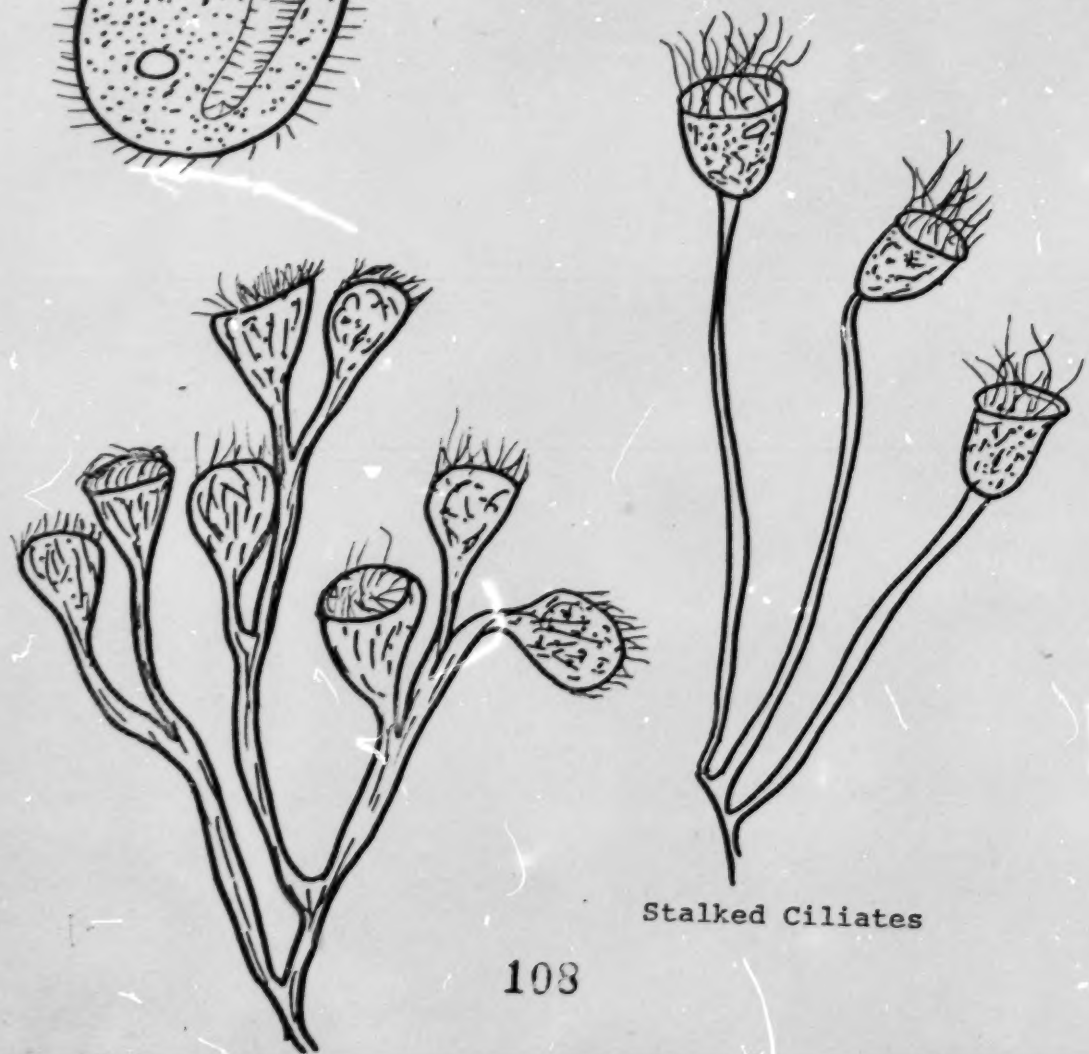


Ameboid

Flagellates



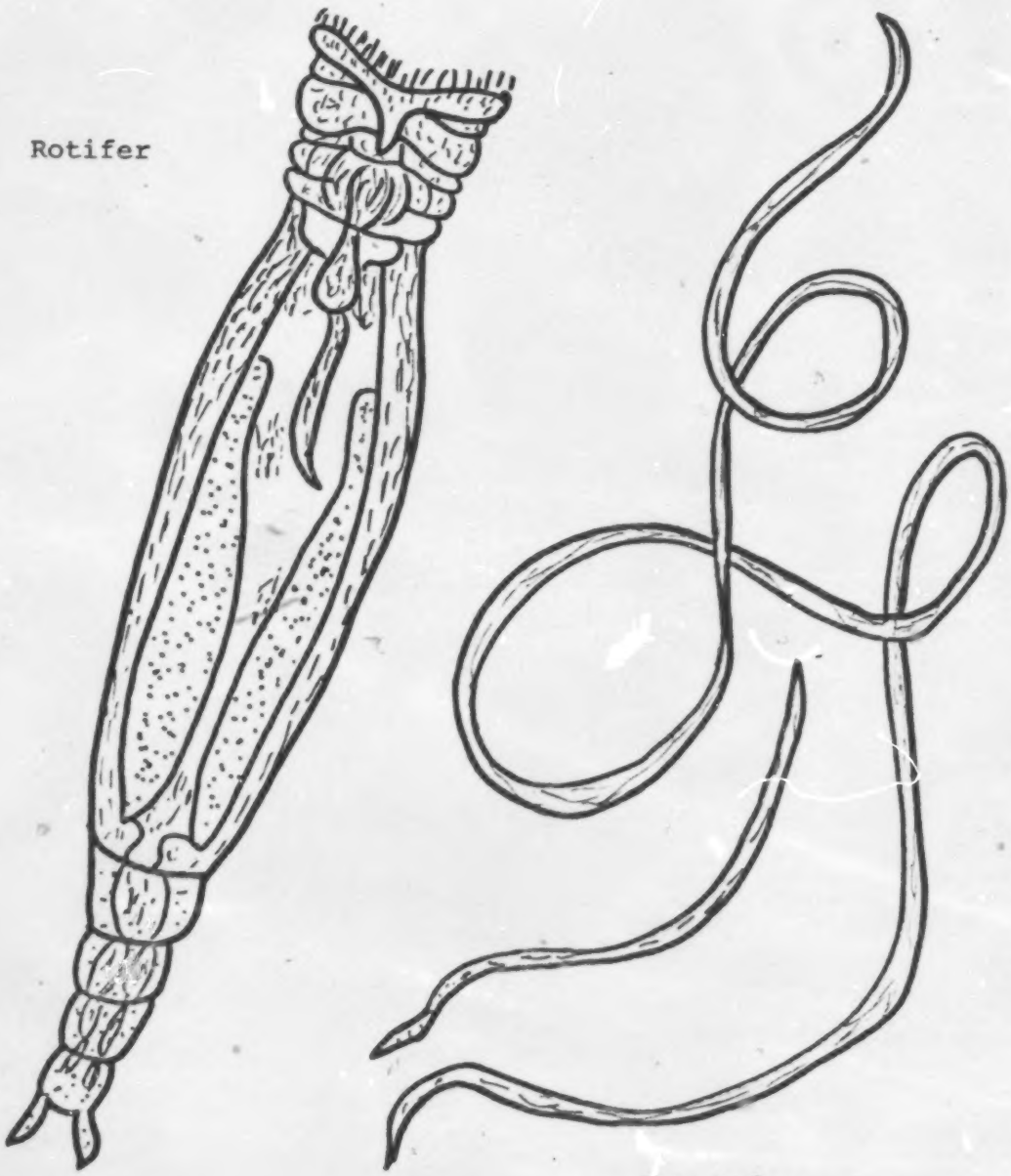
Free Swimming Ciliated Protozoa



Stalked Ciliates

Rotifers and nemetodes are small animals which thrive on the bacterial aggregates. Therefore, they will tend to predominate as the bacteria begin to die and aggregate into flocs which the protozoa cannot use for food.

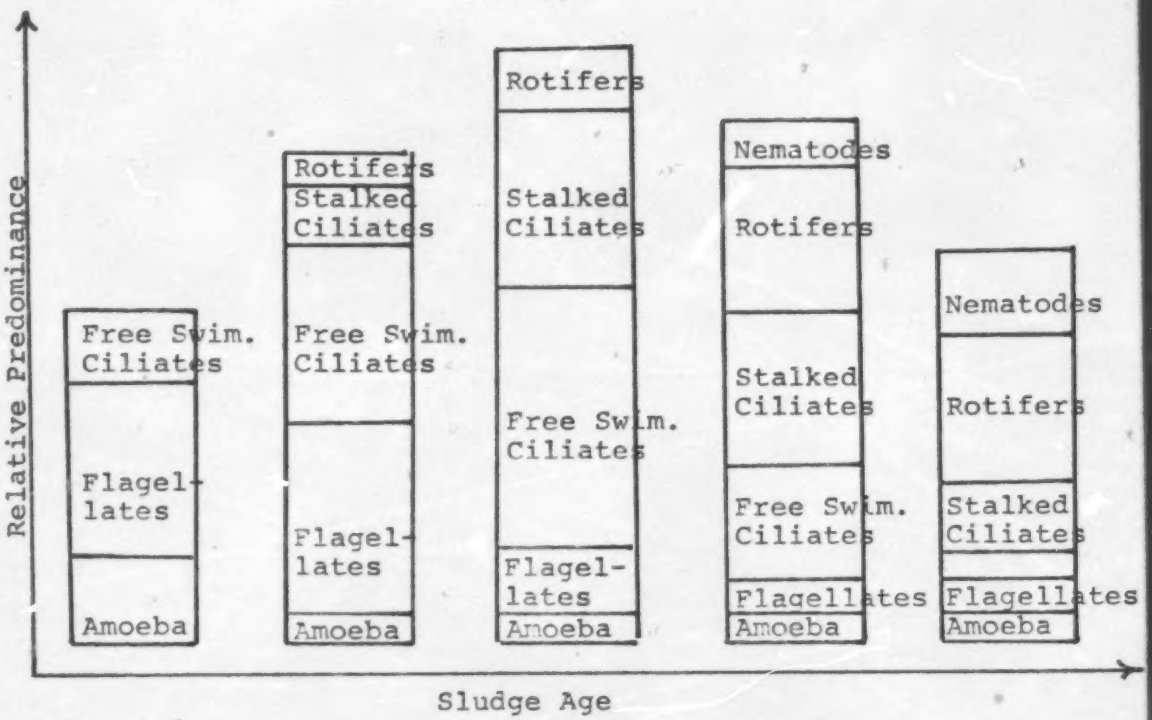
Rotifer



Nemetodes

From this it is obvious that activated sludge combines the activities of the bacteria, protozoa and rotifers to stabilize the wastewater and settle out the insoluble matter. It must be noted that all the organisms are aerobic (need free oxygen to survive). Therefore, the aging of the population takes place only when under aeration and can be used to confirm sludge age.

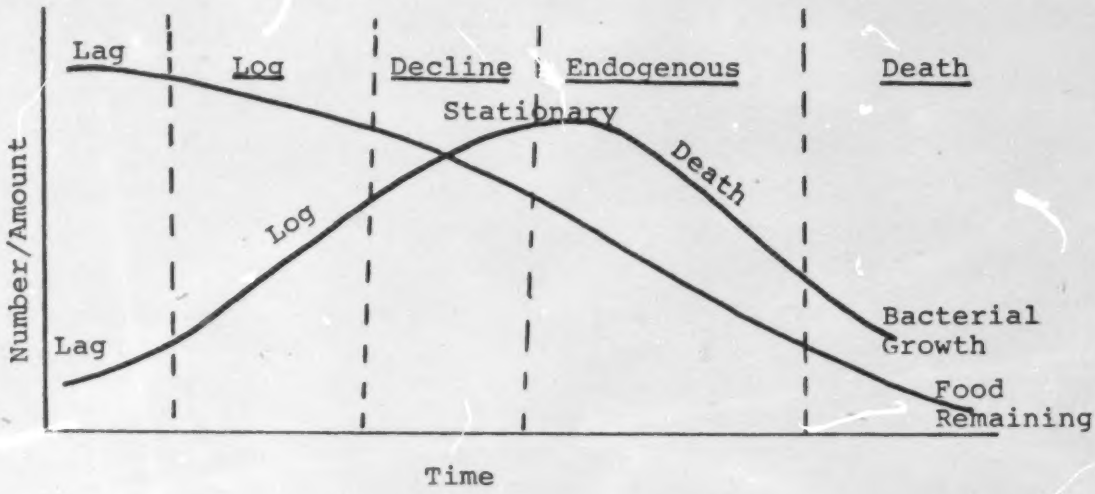
$$\left(\text{sludge age} = \frac{\text{lbs. MLSS}}{\text{lbs. Organic Loading}}\right)$$



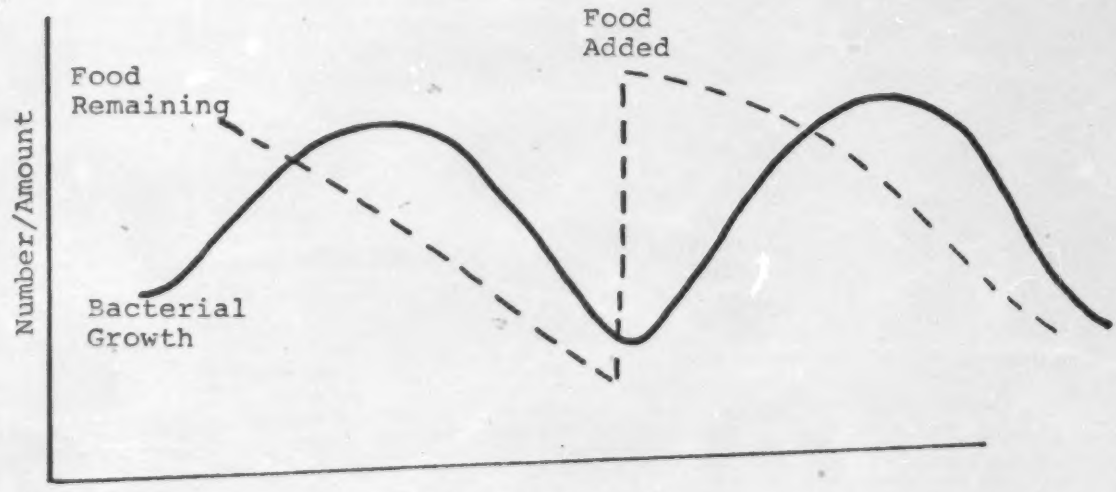
What also is being manipulated is the food - microorganism ratio

$$\text{F/M ratio} = \frac{\text{lbs. BOD}}{\text{lbs. MLSS}}$$

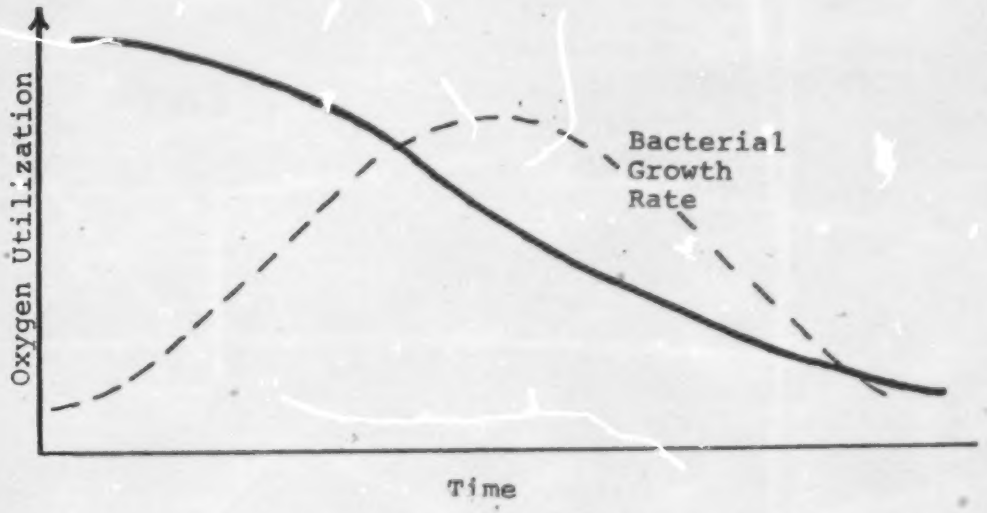
Microbial growth is exponential when F/M ratio is high. As the F/M ratios decline growth rates is proportional to the food remaining (endogenous phase). This normal microbial growth curve can be graphed as follows:



In recirculating the activated sludge an attempt is made to keep the F/M ratio and bacterial growth rate constant. If a "batch process" were visualized the growth curve would look as follows:



Since competition between the organisms is mimimal in this type of system, oxygen is the primary limiting factor (factor which limits growth). Oxygen demand is proportional to bacterial metabolism.



Therefore, oxygen must be added to maintain aerobic conditions as food is added keeping bacterial metabolism at a high rate.

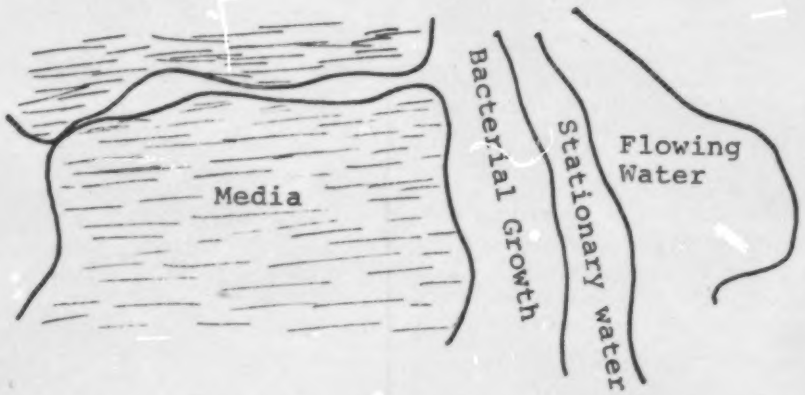
A second limiting factor is nutritional. Carbon, nitrogen, and phosphorous must be in balance. If any one of these is in excess or deficient, the entire system becomes nutritionally deficient. This situation then stimulates growth of fungi and other filamenteous organisms. A suggested ideal carbon-nitrogen-phosphorus (C-N-P) ratio is 100 - 15 - 1.

This type of treatment yields an effluent which is low in microbial activity. Any remaining pathogens are destroyed with the use of a disinfectant such as chlorine. The sludge on the other hand is high in potential microbial activity, hence the term "activated sludge". This sludge can be

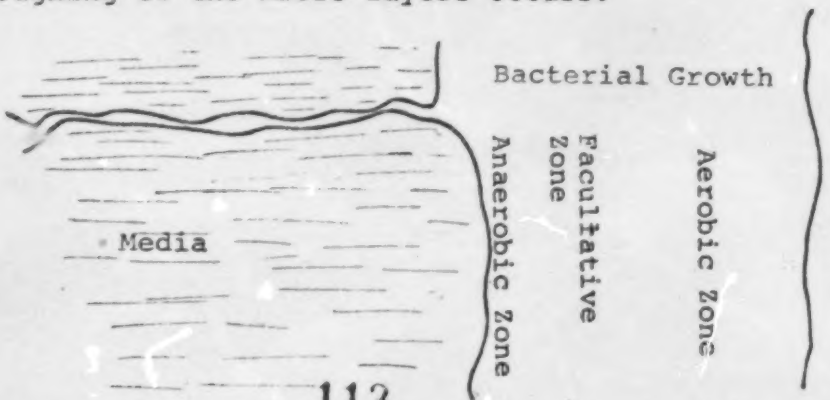
recirculated where the microbes can use the fresh food for new growth. It also can be transferred to a digester where slow microbial action continues to break it down.

TRICKLING FILTERS

Trickling filters are also a biological process. Trickling filters differ from activated sludge in that the microorganisms are grown on a stationary media. The waste is then trickled over the media feeding the microorganisms.



As the growth of the bacteria continues, microlayers develop on the media. As the inner layer becomes anaerobic the microbial action slows and the aerobic organisms show a net die off. As death occurs the adhesive action of these organisms is eliminated and sloughing of the micro-layers occurs.



It must be viewed as strictly a biological filter. It is the bacteria that break down the waste. If it were simply filtered out, the filter would rapidly clog.

The organisms on the filter media are essentially the same as those found in activated sludge. Since these organisms are aerobic and facultative most all of the organic break down takes place on the outer microlayers. Predominant organisms denote the layers with Bacillus, fungi, protozoa, and animals residing in the aerobic layer and the majority of the "working bacteria" in the facultative zone. The anaerobic zone exhibits Desulfavibrio as the predominant population.

The trickling filter can also be looked at as a whole in discussing the bacterial action. The surface will support the growth of algae if it is exposed to sunlight. Fly larva will also develop on the surface. These organisms contribute very little to the stabilization of the sludge.

The upper layers are the areas of high food concentration. Bacteria thrive and the free swimming ciliates are the resultant predominant protozoa. In looking at the microlayers on the media in this area, the bacteria breaking down the organic matter in the waste material form the facultative microlayer with the free swimming ciliates in the aerobic microlayer and staitonary water layer.

As the waste moves through the filter, the concentration of the food decreases. Therefore, on the lower layers the bacteria population decreases with a resultant predominance of the stalked ciliate over the free swimming ciliates. Also

the rotifers begin to appear as flocs are forming.

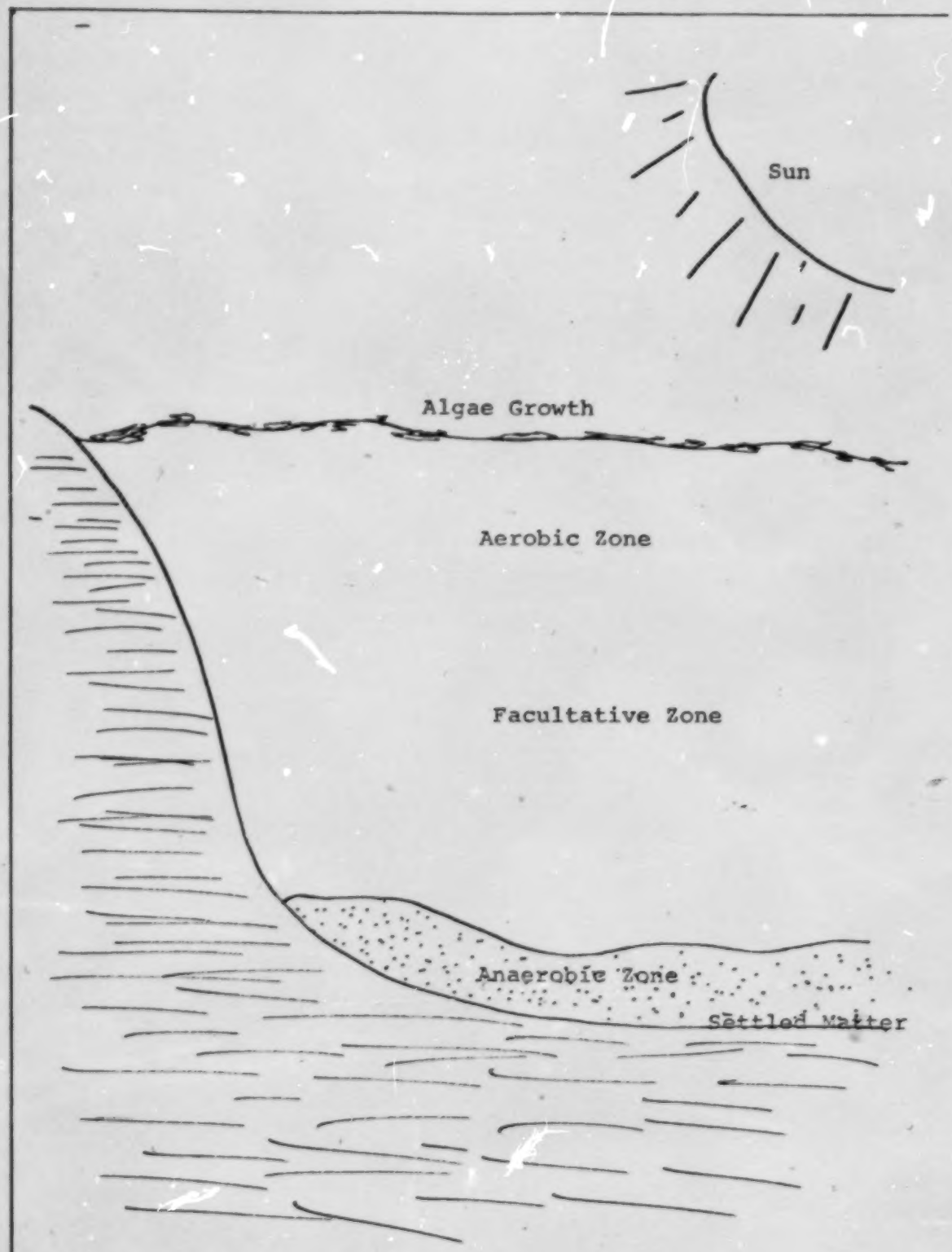
Biological activity of the trickling filter is very similar to that found in activated sludge. However, ocntrol of that activity is very limited in a trickling filter. For this reason populations are not routinely examined.

ROTATING BIOLOGICAL DISCS

The rotating biological disc combines the biological action of the trickling filter and activated slude. The rotating disc facilitates the breakdown of organic matter as the disc turns allowing the liquid waste to trickle over its surface. Sloughing occurs here just as in the trickling filter. The tank of waste in which the disk is rotating shows activated sludge biological characteristics. The system is many times compartmentalized which in theory minimizes mixing of "young" and "old" biologically active material thereby facilitating culturing. With this system no recirculation is then necessary.

LAGOONS

Lagoons biologically break down organic matter using again the same bacterial populations as the activated sludge trickling filters and rotating biological discs. The lagoon differs in that complete treatment takes place within the lagoon. This can be shown by the following diagram:


Sun
Algae Growth
Aerobic Zone
Facultative Zone
Anaerobic Zone
Settled Matter

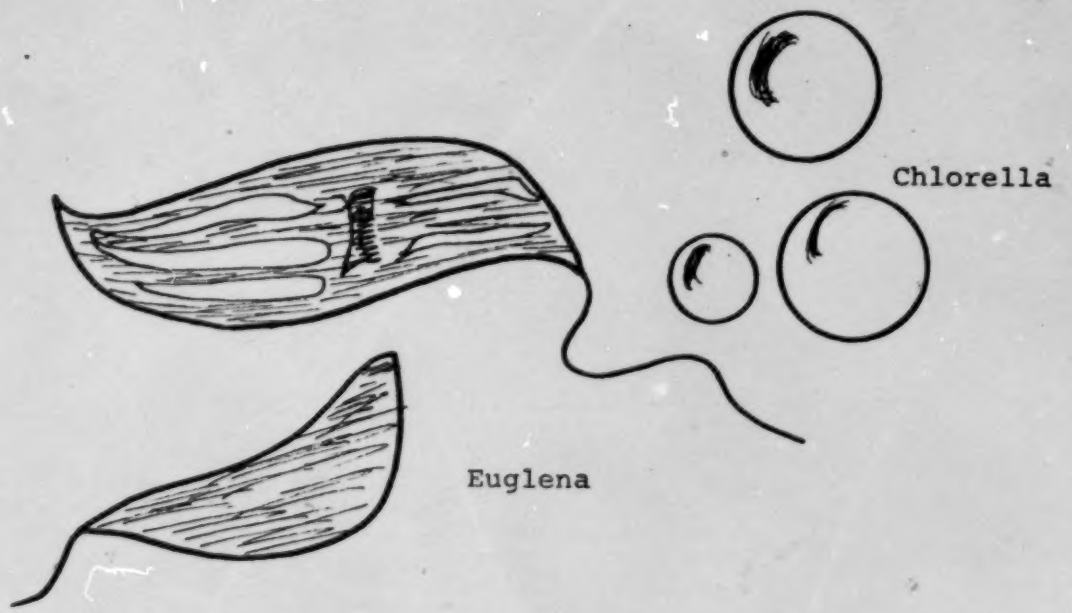
The predominant bacterial populations in a lagoon include Pseudomonas, Flavobacterium, and Alcaligines. These bacteria are facultative. In the summer they thrive in the abundance of oxygen and in winter when the lagoon freezes over their efficiency decreases. As in the other biological systems the predominant protozoan population depends on the bacterial population. The rotifer population appear as discussed before. These animals utilize the bacterial aggregates and algae for food. Therefore, they appear to be more important in clarification rather than purification.

As unused waste settles to the bottom of the lagoon an anaerobic layer is created. In this layer the anaerobic bacteria predominate. Their action is primarily to stabilize the organics not utilized by the aerobic and facultative bacteria. Methane (CH_4), carbon dioxide (CO_2), and ammonia (NH_3) are the primary gaseous biproducts as the digestion of this material takes place.

The useful presence of algae differentiates this system biologically from the others. The algae utilize the CO_2 released by the bacteria for their metabolism and synthesis processes (photosynthesis). During photosynthesis the algae release oxygen which is dissolved into the water. At night however there is no sunlight so the photosynthetic process stops. During this time period the algae use oxygen for metabolism by the same method as the bacteria. However, oxygen utilization by algae at night does not equal the oxygen released during photosynthesis. Therefore, there is a oxygen surplus for use

by the aerobic microorganisms. Oxygen is also supplied to the system through surface aeration.

When nutrient levels are high the phytoflagellates predominate the algae population. These include the Euglena and Chlorella.



These phytoflagellates are photosynthetic and chemosynthetic and therefore aid in waste stabilization. Competition between these algae and bacteria is minimal because the algae are so much larger than the bacteria.

As nutrient levels drop Spirogyra, Vaucheria, and Ultheix appear. These algae are not the flagellates and require less energy. These algae are the filimenteous type green algae.

Overall, nutrient balance will determine the dominant population. The population then determines the breakdown schemes.

SLUDGE DIGESTION

The main objectives of sludge digestion are (1) to oxidize remaining sludge organics to stable end products, (2) to reduce the mass and volume of the sludge, (3) to condition the sludge for further solids handling. To do this bacteria are again used. There are two basic methods of digestion used, aerobic and anaerobic.

Aerobic Digestion

Aerobic digestion makes use of the same bacteria as the biological treatment processes. At this point in time the gross bacterial action is very slow. Nutrients are very low in concentration, bacterial wastes are beginning to

accumulate, and the death rate is exceeding the growth rate. Several parameters affect the rate of sludge digestion. Aerobic digestion is normally run at ambient temperature. It has been shown that raising the temperature 10^{o} C can double the rate of digestion. The amount of dissolved oxygen will also affect the rate of digestion. The bacterial population are primarily aerobic; therefore, the rate of O_2 addition must exceed the rate at which the bacteria utilize it to break down the sludge. Regardless of the rate, adequate time must be allowed.

Anaerobic Digestion

Anaerobic digestion is a continuous process where fresh sludge is added, effluent and gas drawn off and sludge periodically removed. This process is a two stage process where both must occur simultaneously in order for digestion to proceed. First the facultative acid forming bacteria oxidize the remaining organics to organic acids, then the anaerobic methane forming bacteria use the organic acids as food with the release of CH_4 and CO_2. The majority of the stabilization takes place during the second step. 40 - 60% of the organic waste is stabilized by this process.

Anaerobic digestion can only be completed when both stages occur in balance. The methane forming bacteria are very sensitive to any change in pH, temperature, changes in loading and oxygen. Therefore any excess growth of the acid formers will lead to a build up of organic acids. This depresses

the pH and will prevent optimal growth. Therefore the primary biological concern in anaerobic sludge digestion is to keep the methane formers happy.

DISINFECTION

Disinfection is a term commonly heard in wastewater treatment. Disinfection does not mean the same as sterilization. Sterilization refers to the destruction of all living organisms. Disinfection, on the other hand, refers to only the destruction of those organisms which can transmit disease. Disinfection is achieved through physical and/or chemical means, not biologically.

During biological treatment processes most of the disease causing organisms (pathogens) die or are removed. Disinfection is used to destroy any pathogens which may survive treatment.

Disinfection by physical means can be accomplished by exposure to heat or light. Raising the temperature of water to its boiling point will effectively destroy water borne pathogens. Large scale use of this method is impractical but during emergency situations, where waste has contaminated drinking water supplies, will satisfactoraly protect the public from pathogen infection. The use of ultraviolet light has also been examined as a disinfectant for potable water but is unacceptable for wastewater effluent disinfectinon. The reason is that, in order for ultra-violet light to properly disinfect the water, it must be free of light absorbing substances and suspended matter.

Chemical disinfectants have the advantage of a residual for added protection. The oxidizing chemicals including halogens, potassium permanganate and ozone are the most commonly used. Of these chlorine is the disinfectant of choice. Five basic factors affecting disinfection by chlorine are:

1. Type of organism: Spore formers are more resistant than non-spore forming facteria. Viruses, being non-cellular, pose another problem in being even more resistant than the indicator organism E. coli. Aggregates of bacteria and viruses create highly resistant groups also. Again these groups show higher resistance than E. Coli. Even so, E. Coli or the Fecal Coliform test provides the most reliable indicator of effectiveness of disinfection.
2. Disinfectant concentration: The concentration of disinfectant must be sufficient to inactivate essential enzyme activity of the bacteria.
3. Nature of the wastewater effluent being disinfected: Suspended matter creates a protective barrier.
4. Temperature
5. Contact time

In wastewater disinfection what is being strived for is a significant reduction of the indicator organism E. Coli. This is confirmed by the Fecal Coliform analysis. A significant reduction in these organisms indicates destruction of the pathogens.

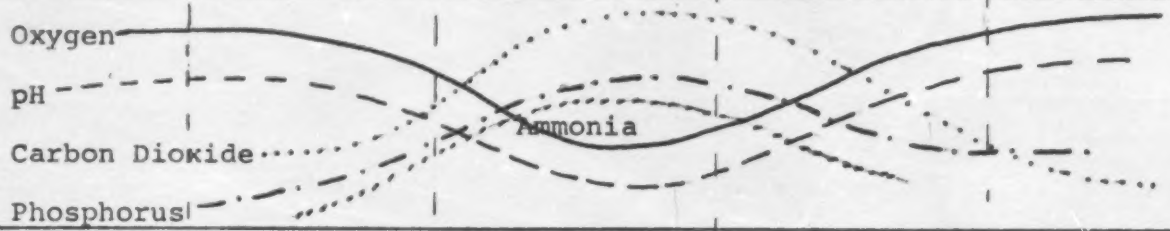
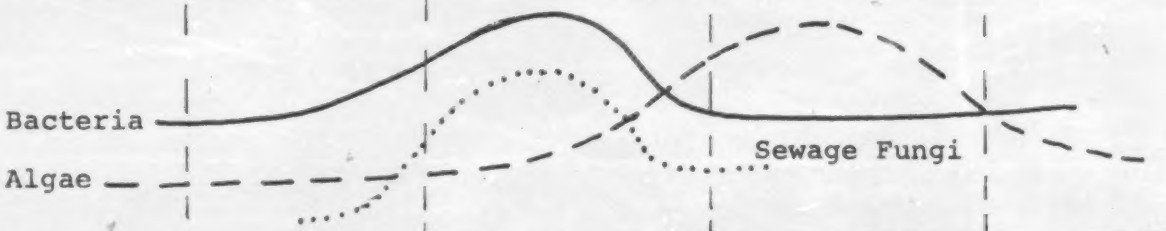
EFFLUENT AND RECEIVING STREAM

The effect of the effluent on the receiving stream is directly proportional to the amount of material in the effluent which requires decomposition. Bacteria require oxygen for this action in the receiving stream just as in the secondary treatment processes. As the oxygen is used by the bacteria the amount of dissolved oxygen in the stream water decreases. This and the effects on stream life can be shown by the diagram on the next page.

The ideal situation would be effluent of such quality that this decrease in dissolved oxygen is minimal or non-existant. Stream flow plays an important role. The more the discharge can be diluted the less of an effect a particular discharge will have on a stream.

THE EFFECT OF ORGANIC POLLUTION ON STREAM LIFE

Current →

Zone	Clean	Degradation	Septic	Recovery	Clean
Levels of Chemicals Oxygen Carbon Dioxide Ammonia Phosphorous pH					
Invertebrates (dominant species)	Caddis Fly May Fly	Simulium Chironomus	Tubifex Culex	Simulium Chironomus	Caddis Fly May Fly
Fish (dominant species)	Bass Trout	Carp Gar Buffalo	Few Fish Present	Carp Gar Buffalo	Bass Trout
Plankton (dominant species)	Navicula Dinobryon	Paramecium Stentor	Oscillatoria Melosira	Pandorina Euglena Spirogyra	Navicula Dinobryon
Numbers of Bacteria, Algae, and Sewage Fungi					

Module No:	Module Title: Biology for Operators
Approx. Time: 1 hour	Submodule Title: Organisms and Their Relationships
	EVALUATION

Objectives:

Upon completion of this module, the participant should be able to correctly answer 75% of the evaluation questions on Organisms and Their Relationships.

1. The procaryotic cell is more structurally complicated than the encaryotic cell.

   _____a. True

   _____b. False

2. Binary fission is

   _____a. The method by which all cells reproduce.

   _____b. A method by which procaryotic cells reproduce.

   _____c. A method by which encaryotic cells reproduce.

3. Match the following characteristics to cell group.

   _____a. Large central vacuoles
   Chloroplasts
   Cell walls

   _____b. No chloroplasts
   Centrioles
   No cell walls
   Locomotion

   _____c. DNA not organized in chromosomes
   Chromatophores
   No lysosomes, centrioles, or mitochondria

   1. Plant cells
   2. Animal cells
   3. Protistan cells
   4. Moneran cells

4. In the classification hierarchy which of the following order is correct.

   _____a. Class-Order-Family-Genus

   _____b. Order-Family-Class-Genus

   _____c. Family-Order-Class-Genus

   _____d. Class-Genus-Order-Family

5. Plants require specialized breathing apparatus for respiration.

   _____a. True

   _____b. False

6. Nutrition can be defined as the intake and distribution of raw materials to all cells within an organism.

   _____a. True

   _____b. False

7. Plants can manufacture amino acids as they are required.

   _____a. True

   _____b. False

8. Photosynthesis produces _____ as a gaseous biproduct.

   _____a. Nitrogen

   _____b. Carbon monoxide

   _____c. Oxygen

   _____d. Carbon dioxide

9. Match the plant group to its primary importance.

_____a.	Grain	1. Gymnosperms
_____b.	Fruits and vegetables	2. Monocots
_____c.	Lumber	3. Dicots

10. Animals could survive without the plant kingdom.

    _____a. True

    _____b. False

11. The animal kingdom is composed of only two phyla.

    _____a. True

    _____b. False

12. Humans are a member of the phylum.

_____a. Arthropoda

_____b. Bryophyta

_____c. Chordata

_____d. Dominata

13. Animal synthesis

_____a. Is identical to plant photosynthesis.

_____b. Is complete in that animals can synthesize all nutrients from the inorganic starting materials.

_____c. Requires sunlight.

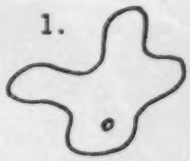
_____d. Requires essential nutrients from which to build other nutrients.

14. Match the diagram of the protozoa to the proper label.

_____a. Flagellated

_____b. Ciliate

_____c. Ameboid

1. 

2.

3.

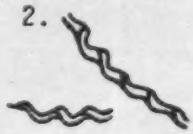
15. Match the diagram of the bacteria to the proper label.

_____a. Bacilli

_____b. Cocci

_____c. Spirillium

1.

2. 

3.

16. Plants are the producers on the food pyramid and animals the consumers.

_____a. True

_____b. False

17. Denitrifying bacteria transform nitrogen compounds into forms which are useable to plants.

_____a. True

_____b. False

18. Mushrooms and plants demonstrate a

    _____a. Parasitic relationship

    _____b. Mutualistic relationship

    _____c. Commensalistic relationship

    _____d. Saprophytic relationship

19. Decomposing Bacteris

    _____a. Convert NH_3 to atmospheric nitrogen

    _____b. Aid in the breakdown of animal wastes to NH_3

    _____c. Convert NO_2 to NO_3

    _____d. Fix atmospheric nitrogen into nodules on plant roots.

20. Fungus infections are a job of

    _____a. Saprophytism

    _____b. Bositism

    _____c. Parasitism

    _____d. Mutulism

Module No:	Topic: EVALUATION

Instructor Notes:	Instructor Outline:
Evaluation Handout A Answers: 1. b 2. b 3. a - 1 b - 2 c - 4 4. a 5. b 6. a 7. a 8. c 9. a - 2 b - 3 c - 1 10. b 11. b 12. c 13. d 14. a - 2 b - 3 c - 1 15. a - 3 b - 1 c - 2	Give the participants Part A of the Biology for Operators Evaluation after completing the submodule over Organisms and Their Relationships.

Module No:	Topic: EVALUATION

Instructor Notes:	Instructor Outline:
16. a 17. b 18. d 19. b 20. c	

Module No:	Module Title: Biology for Operators
	Submodule Title: Water Supply Concerns
Approx. Time: 1 hour	EVALUATION

Objectives:

Upon completion of this module, the participant should be able to correctly answer 80% of the evaluation questions over the Water Supply Concerns portion of the Biology for Operators module.

Evaluation Questions

Choose the best answer

1. Sulfur bacteria are capable of

   _____a. Transforming organic sulfur to NO_3

   _____b. Oxidize sulfur found in organic forms

   _____c. Reduce oxidized sulfur to H_2S

   _____d. All of the above

2. Desulfovibrio reduces sulfur compounds to H_2S in oxygen deficient waters.

   _____a. True

   _____b. False

3. Match the area of iron deposit to the type of bacteria.

_____a. Thiobacillus furooxidans	1. Surrounding waters
_____b. Liptothux	2. Iron incrusted sheath
_____c. Gallionella ferruginea	3. Ferric hydroxide filaments

4. The best control measure for iron bacteria is

   _____a. Prevention of entrance into well

   _____b. Routine acid treatment

   _____c. Periodic copper sulfate treatment

5. Algae can produce

_____a. Objectional tastes and odors

_____b. Modified pH and alkalinity

_____c. Color, turbidity and radioactivity problems

_____d. All of the above

6. Synura is one of the more potent odor producing algae which produces a septic odor at low concentrations.

_____a. True

_____b. False

7. _____ are the most important filter clogging algae.

a. Filamentous

b. Diatoms

c. Flagellates

d. Ameboids

8. Indirectly algae can affect the rate of pipe corrosion in the distribution system.

_____a. Decreasing the dissolved oxygen supply.

_____b. Creating a luminiscence in the pipes.

_____c. Increasing organic matter in the pipes.

_____d. Both a and c

9. Tastes and odors are produced primarily in the distribution system; therefore, filtration to remove the algae will eliminate most taste and odor problems.

_____a. True

_____b. False

10. Match the following characteristics to the algae.

_____a. Synura	1. Slime producer
_____b. Volvox	2. Produces fishy odors at low levels
_____c. Myxophyceae	3. Clogs filters
_____d. Diatom	4. Imparts a bitter metallic taste to the water.

11. Pathogens occur in low concentrations in potable water supplies.

_____a. True

_____b. False

12. One can differentiate salmonella and shigella by visual inspection.

_____a. True

_____b. False

13. Match the disease with the microorganism.

_____a. Salmonella	1. Dysentary
_____b. Shigella	2. Typhoid fever
_____c. A virus	3. Amoebic dysentary
_____d. Estamoeba	4. Hepatitus

14. Chlorination is more rapid than ozone in disinfection of water.

_____a. True

_____b. False

15. Since wells tap underground water supplies

_____a. Pathogens are always present

_____b. The water is naturally bacteriocidal

_____c. Contamination with pathogens is low in frequency.

_____d. None of the above

Module No:	Topic: EVALUATION

Instructor Notes:	Instructor Outline:
Evaluation Handout B Answers 1. c 2. a 3. a - 1 b - 2 c - 3 4. a 5. d 6. b 7. b 8. c 9. b 10. a - 4 b - 2 c - 1 d - d 11. b 12. b 13. a - 2 b - 1 c - 4 d - 3 14. b 15. c	Give the participants Part B of the Biology for Operators Evaluation after completing the submodule over Water Supply Concerns.

Module No:	Module Title:
–	Biology for Operators
	Submodule Title:
Approx. Time:	Wastewater Stabilization
1 hour	EVALUATION

Objectives:

Upon completion of this module, the participant should be able to correctly answer 80% of the evaluation questions over Wastewater Stabilization.

Evaluation Questions

1. In fresh sewage there is approximately

   _____a. 1×10^5 bacteria per milliliter

   _____b. 1×10^7 pathogenic bacteria per milliliter

   _____c. 1×10^5 microorganisms total per milliliter

   _____d. 1×10^7 viable organisms per liter

2. H_2S production in sewer pipes is primarily due to the action of

   _____a. Sulfur-oxidizing bacteria

   _____b. Sulfate-reducing bacteria

   _____c. Nitrifying bacteria

   _____d. Escherchia coli

3. Corrosive action of sulfur bacteria is due in part to the Thiobacillus oxidizing H_2S to H_2SO_4

   _____a. True

   _____b. False

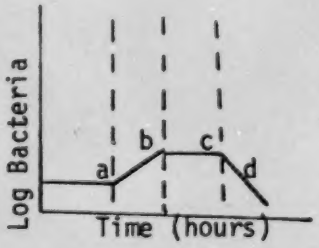
4. Label the following graph indicating the growth phases of the bacteria

   a. _____

   b. _____

   c. _____

   d. _____



5. The trickling filter is biologically a _____ system.

   _____a. Strictly aerobic

   _____b. Faculative

   _____c. Strictly anaerobic

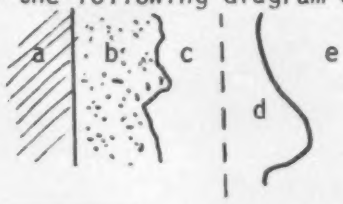
   _____d. Poor

6. Algae play an important role in trickling filter biology by actively degrading and stabalizing wastewater.

   _____a. True

   _____b. False

7. Label the following diagram of flow over a trickling filter.



   a. _____

   b. _____

   c. _____

   d. _____

   e. _____

8. Primary treatment is a biological treatment.

   _____a. Tru

   _____b. False

9. Algae are essentia. in oxidation ponds since they help maintain aerobic conditions.

   _____a. True

   _____b. False

10. Certain bacteria found in an oxidation decompose organic matter in oxidation ponds yielding CH_4, CO_2 and NH_3. This reaction takes place in the _____ zone of the pond.

    a. Aerobic

    b. Facultative

    c. Anaerobic

11. If an oxidation pond freezes over in the winter, it becomes essentially _____.

    a. Aerobic

    b. Facultative

    c. Anaerobic

12. Disinfection destroys all viable bacteria found in wastewater effluent.

    ___a. True

    ____b. False

13. The bacteria population found in an anaerobic digester is highly specialized.

    ____a. True

    ____b. False

14. The activity in activated sludge is

    ____a. Strictly mechanical

    ____b. Combination of mechanical and biological actions

    ____c. Strictly biological

15. Which of the following are part of population found in a balanced activated sludge system?

    ____a. Stalked ciliates

    ____b. Algae

    ____c. Free swimming ciliates

    ____d. Flagellates

    ____e. Amoeboids

16. The balance of the predominant species in an activated sludge system indicates the availability and type of nutrients present and therefore relates to process control.

    _____a. True

    _____b. False

17. Nocardia present in an activated sludge system indicates

    _____a. An ideal system

    _____b. Nothing

    _____c. The system is upset

18. The breaking point range between the mesophilic and thermophilic bacteria in an anaerobic digestion system is

    a. 60 - 80° C

    b. 43 - 60° C

    c. 24 - 38° C

    d. 38 - 43° C

19. Anaerobic digestion systems are designed to yield a system where the death rate _____ the growth rate of the bacteria present.

    a. Exceeds

    b. Equals

    c. Is less than

20. Fecal coliform levels in wastewater effluent indicate

    _____a. The effectiveness of the treatment processes

    _____b. The level of dissolved oxygen in the wastewater effluent

    _____c. The probability of the presence of pathogens.

    _____d. Both a and c

Module No:	Topic: EVALUATION

Instructor Notes:	Instructor Outline:
Evaluation Handout C Answers 1. a 2. b 3. a 4. a. Lag phase b. Log phase or exponential growth phase c. Stationary phase d. Death phase or decline phase 5. b 6. b 7. a. Stone b. Microorganisms c. Fixed water d. Moving water e. Air 8. b 9. a 10. c 11. c 12. b 13. a 14. c	Give the participants Part C of the Biology for Operators Evaluation after completing the submodule over Wastewater Stabilization.

Module No:	Topic: EVALUATION
Instructor Notes:	Instructor Outline:

15. a, c, d, e
16. a
17. c
18. d
19. a
20. d